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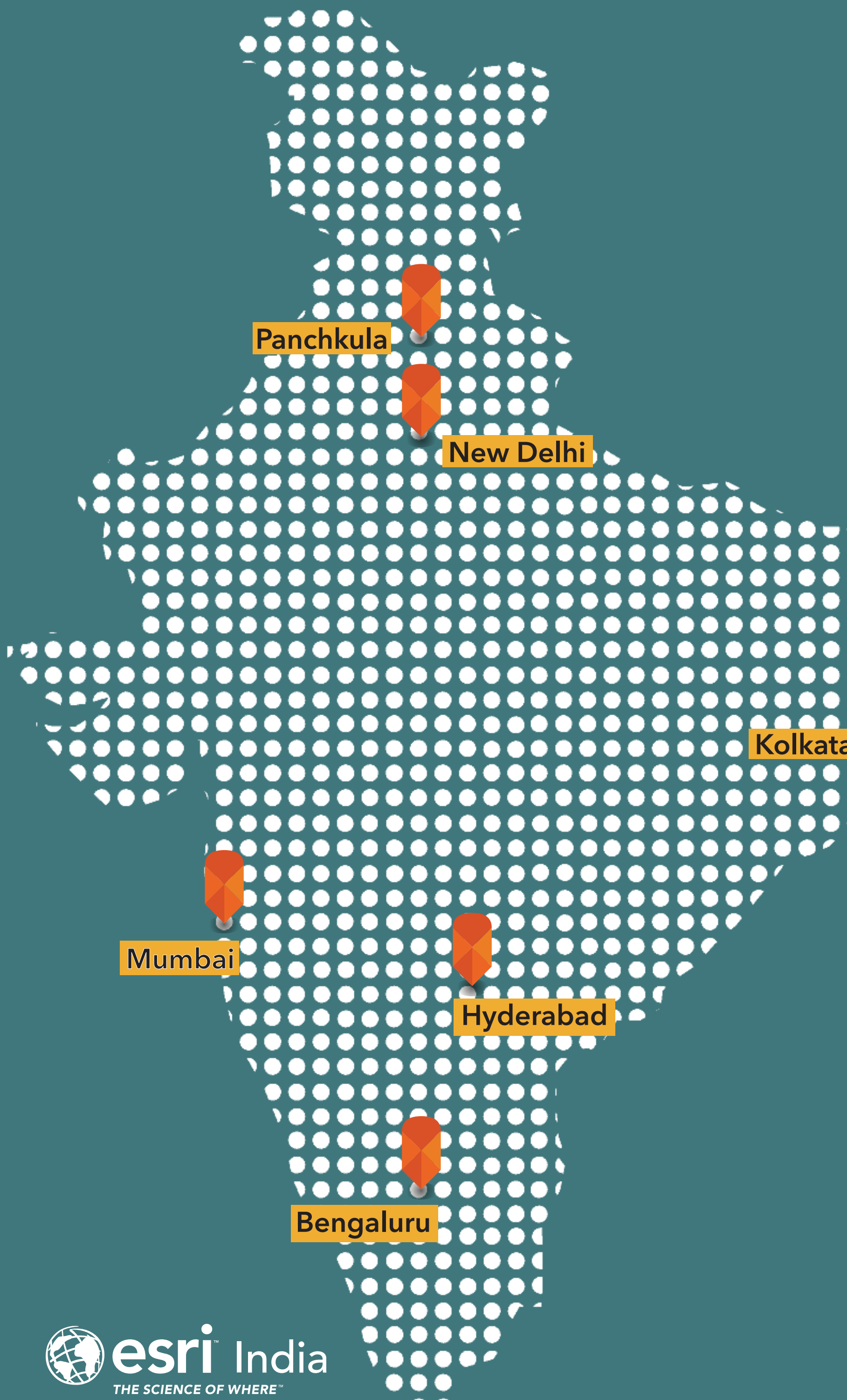

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MD'S DESK

Agendra Kumar
Managing Director, Esri India

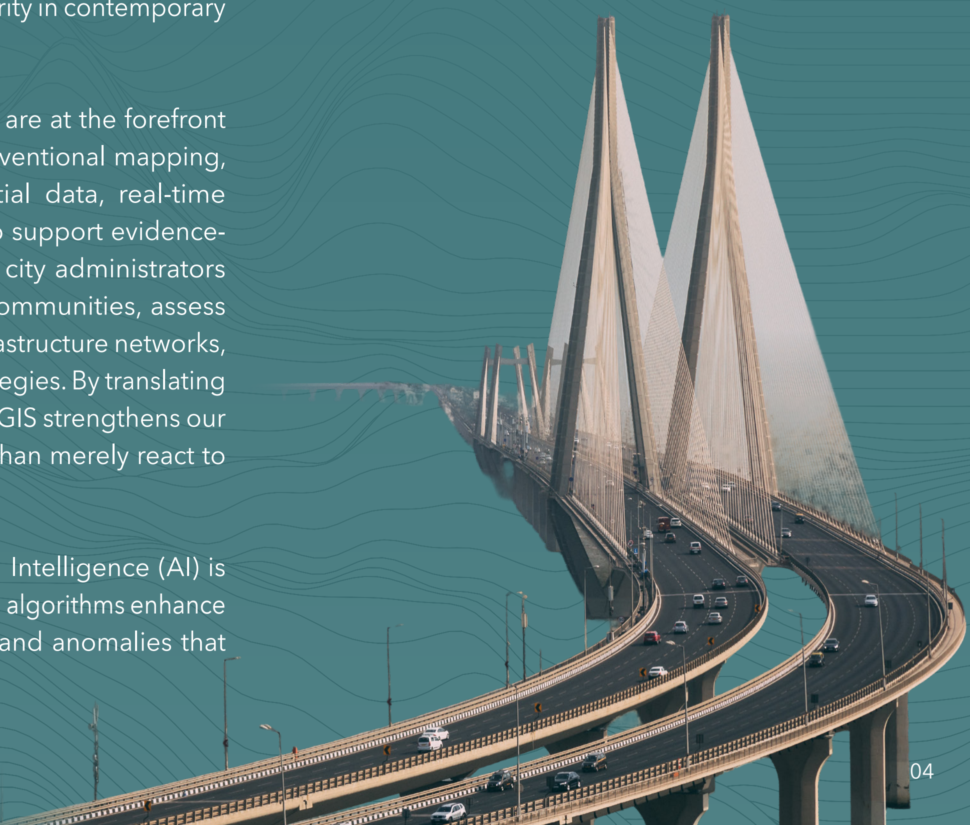
As urban areas continue to expand amid escalating challenges such as climate change, rapid population growth, increasing infrastructure demands, and environmental degradation, resilience has emerged as a central priority in contemporary urban governance and planning.

Geographic Information Systems (GIS) are at the forefront of this transformation. Far beyond conventional mapping, GIS enables the integration of spatial data, real-time information, and advanced analytics to support evidence-based decision-making. It empowers city administrators and planners to identify vulnerable communities, assess climate and disaster risks, optimize infrastructure networks, and enhance emergency response strategies. By translating complex data into clear visual insights, GIS strengthens our ability to anticipate challenges rather than merely react to them.

The convergence of GIS with Artificial Intelligence (AI) is further accelerating this impact. AI-driven algorithms enhance spatial analysis by detecting patterns and anomalies that may otherwise go unnoticed. Machine learning models, when integrated with GIS platforms, can forecast flood zones, predict urban heat island effects, model traffic congestion, and optimize resource distribution. AI also enables automated image classification from satellite and drone imagery, improving the speed and accuracy of land-use mapping, environmental monitoring, and damage assessment following disasters. Together, GIS and AI create a powerful ecosystem of predictive intelligence that supports proactive urban planning and resilient infrastructure design.

GIS supports integrated planning by connecting data across sectors, ensuring that development is inclusive and sustainable. When enhanced by AI capabilities, geospatial systems can simulate future scenarios, evaluate policy impacts, and guide long-term investments with greater precision and confidence.

As we look to the future, the integration of GIS and AI will play a defining role in shaping cities that are adaptive, intelligent, and prepared for uncertainty. Our efforts should collaboratively inspire meaningful dialogue and innovative action toward building urban environments that are not only smart but truly resilient.



Esri India Introduces Bharat ENVI to tap the fast-growing satellite data analytics market

Esri India has launched Bharat ENVI, a geospatial image processing and analysis software. Bharat ENVI brings world-class remote sensing and analytics capabilities to Indo ArcGIS users, allowing them to make more informed decisions for better governance and economic growth.

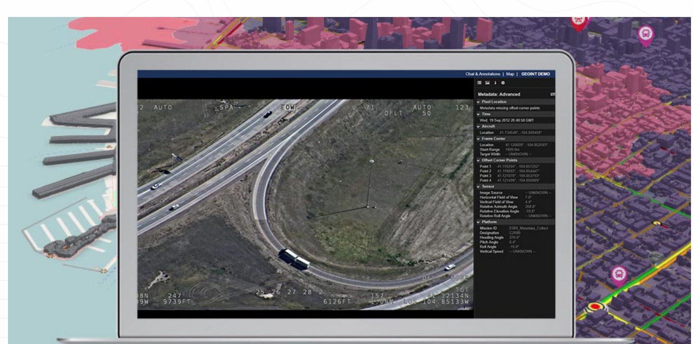
ENVI has long been recognized worldwide as a leading solution for extracting actionable insights from remote sensing data from various sources, including satellite, drone, LiDAR, SAR, multispectral, and hyperspectral sensors. It is tightly integrated with Esri's ArcGIS platform and lets GIS users seamlessly access and analyze imagery to solve critical problems with confidence.

Indian GIS user organizations can now combine the power of Indo ArcGIS with Bharat ENVI, leveraging the large repository of Indian content and AI models in Indo ArcGIS Living Atlas. This tightly integrated capability is crucial for a range of activities, including land-use planning, resource management, and effective policy implementation.

Bharat ENVI also includes an essential toolset, accessible to both experts and new users. This intuitive toolset allows satellite imagery users to automate the extraction of features like water bodies, mining pits, crops, settlements, etc., from readily available satellite datasets, such as Landsat 8, Sentinel-2, and Sentinel-1. It is also capable of extracting building footprints and detecting ships through advanced deep learning techniques.

Agendra Kumar, Managing Director, Esri India, said, "The introduction of Bharat ENVI strengthens the geospatial technology ecosystem in the country. As organizations increasingly rely on satellite imagery and remote sensing for planning, sustainability, and national development, Bharat ENVI's advanced analytics will significantly complement the capabilities of Indo ArcGIS, widely used across India."

The availability of Bharat ENVI will enable more than 1.2 million ArcGIS users from over 6500 organizations in India to access powerful ENVI image processing tools directly within the ArcGIS environment, while benefiting from localized datasets, analytical tools, and AI capabilities.



Esri India and TERI SAS Ink Pact to Advance Geospatial Education and Research

Esri India has formalized a Memorandum of Understanding (MoU) with The Energy and Resources Institute School of Advanced Studies (TERI SAS), a Deemed-to-be University, to advance geospatial education, capacity building and applied research in India.

Through this strategic collaboration, both organizations will combine their complementary strengths in undertaking initiatives that promote the use of GIS technology for governance and sustainable development. Leveraging TERI SAS's expertise in environment, energy, and sustainability with Esri India's cutting-edge geospatial technology leadership, this collaboration will span multiple programs to foster a robust geospatial ecosystem in India.

Agendra Kumar, Managing Director, Esri India, said, "This collaboration with TERI SAS represents a significant step in strengthening India's geospatial education ecosystem. By combining our advanced GIS technology with TERI SAS's academic rigor and research excellence in sustainability, we are creating a powerful platform to train the next generation of geospatial professionals and decision-makers. Through joint capacity-building initiatives and curriculum alignment, we aim to drive the adoption of data-driven, location-based approaches in critical areas, including urban planning, environmental management, disaster resilience, and infrastructure development. This collaboration exemplifies how academic institutions and industry can work together to build India's self-reliance in geospatial intelligence and innovation."

Prof. Suman K Dhar, Vice Chancellor, TERI SAS, added, "This MoU is designed to foster collaboration on state-of-the-art geospatial tools and techniques to build a workforce of Geoinformatics professionals, enabling a transition toward a greener and sustainable future. TERI SAS, being at the forefront of education in the sustainability domain, hopes to play a transformative role in the critical area of 'Geoinformatics AI for Sustainability'."

The MoU will lead to initiatives such as faculty training programs under the GIS Academia Council of India (GACI) framework, curriculum enhancements for university-level GIS education, capacity-building workshops for government officials, and applied research projects. TERI SAS and Esri India will also jointly facilitate advanced learning through guest lectures by industry experts, student workshops, and innovation challenges to bridge the gap between academic learning and real-world GIS applications.

Indo ArcGIS Living Atlas Recognized as the Geospatial Data Platform of the Year

At GeoSmart India 2025, Esri India was honoured with the GeoSmart India Leadership Award for Indo ArcGIS Living Atlas, which was recognized as the Geospatial Data Platform of the Year.

Indo ArcGIS Living Atlas is an evolving collection of ready to-use geographic content for India to create maps, apps, and perform analysis. This recognition reinforces Esri India's commitment to advancing one of the country's most comprehensive and dynamically evolving geospatial data platforms.

Esri India Wins ASSOCHAM National Water Award

Esri India's ArcGIS-based Sewerage Management System, developed for the Municipal Corporation of Greater Mumbai (MCGM), got recognized as an 'Innovative Water Technology/ Product' at the ASSOCHAM (The Associated Chambers of Commerce and Industry of India) National Water Awards 2025.

This recognition reaffirms the transformative role of GIS in shaping the smart, resilient cities of tomorrow.


ASSOCHAM

ASSOCHAM NATIONAL WATER AWARDS 2025

This is to certify that product

GIS-based Sewerage Management System

offered by

Esri India Technologies Private Limited

*has been rated as "**The Winner**" in the "**Innovative Water Technology & Product**" Category.*

This has been based on evaluation by the jury at the National Level Competition for excellence in Water Management 2025.

Mr Manish Singhal
Secretary General
ASSOCHAM

Mr Mohd. Shaffi
Chairman
ASSOCHAM National
Council on Water

Esri India Customers Win Awards

During the Awards Ceremony at GeoSmart India 2025, alongside leading organizations and government departments from across the country, BMSK, BPCL, and ASDMA were recognized for the remarkable impact they have created through the transformative use of GIS.

Bihar Mausam Seva Kendra (BMSK) was awarded the **Excellence in Technology Award - Climate Change Management,** for leveraging GIS to transform weather data into actionable insights, strengthening flood preparedness and climate resilience in Bihar.

Bharat Petroleum Corporation Limited (BPCL) was awarded the **Excellence in Technology Award - Location Intelligence,** for successful adoption and implementation of an enterprise-level geospatial business intelligence solution across multiple business units to drive strategic planning, optimize operations, accelerate market expansion, and enable data-driven decision-making at scale.

Assam State Disaster Management Authority (ASDMA) was awarded the **Excellence in Policy Award - Disaster Management,** for effectively integrating GIS, remote sensing, hazard mapping, and real-time analytics to strengthen disaster preparedness and early warning systems in one of India's most disaster-prone regions.

The work these organizations are doing exemplifies how GIS and Location Intelligence are driving innovation, sustainability, and resilience across sectors, setting new milestones for geospatial adoption in India.

Transforming Urban Development and Governance with GIS

As populations increase and urban areas expand, urban planning faces novel challenges. These new challenges require innovative use of technology. Through the effective use of smart technologies like GIS, AI, GeoAI, and Digital Twins, it is possible not only to overcome these challenges but also to achieve optimal living conditions for present and future generations.

GIS for Urban Planning and Development

GIS tools are beneficial for different departments within municipal corporations, such as urban planning, transportation, environmental, disaster management, and urban renewal. ArcGIS offers a comprehensive suite of tools and capabilities tailored specifically to address the unique challenges and complexities of urban and regional planning. By integrating data from various sources and visualizing it on interactive maps, ArcGIS enables municipal corporations to gain a deeper understanding of spatial relationships, patterns, and trends. This enhanced understanding helps urban planners, government agencies, and stakeholders make informed decisions, optimize resources, and create sustainable and resilient communities

Development Planning

Unplanned urban growth often leads to informal settlements, encroachments on public land, and development in environmentally sensitive areas such as wetlands and floodplains. Such growth puts pressure on basic services like water supply, sanitation, and transportation, while also increasing vulnerability to disasters.

GIS allows for spatial analysis of encroachment data, identifying patterns, hotspots, and areas with a high concentration of encroachments. Mapping tools provide visual representations of encroachments, helping authorities prioritize removal efforts. Mobile applications like ArcGIS Field Maps facilitate field data collection, allowing enforcement officers to capture real-time information about encroachments, document evidence through photos and videos, and update the central database. This streamlines the process of data collection, monitoring, and tracking progress in encroachment removal efforts.

Combined with satellite imagery and drone surveys, GIS also allows authorities to detect unauthorized constructions by comparing approved building plans with actual ground conditions. Change detection analysis can identify new structures, additional floors, or land-use violations. This enables faster regulatory enforcement, reduces corruption, and ensures compliance with urban planning norms.

Change detection analysis reaches new heights with GeoAI. Change detection models compare multi-temporal images to identify newly constructed buildings or urban sprawl. This helps urban planners quantify the rate of expansion, assess loss of vegetation, monitor encroachment into environmentally sensitive zones, and evaluate infrastructure development. GeoAI supports smart city planning by enabling predictive modeling of future growth patterns, optimizing transportation networks, and identifying high-risk zones for flooding or heat island effects. GeoAI provides an efficient, scalable, and data-driven approach for sustainable urban management and policy decision-making.

Compliance Management

Inefficient land administration systems delay development projects and discourage investment. Transparent land records, digital cadastral systems, and strong regulatory frameworks are essential for effective urban governance and sustainable land management.

GIS integrates cadastral maps, taxation zones, and underground/overground utility networks into a single spatial platform. By overlaying proposed building layouts with property boundaries and zoning regulations, authorities can quickly verify whether a development complies with approved land use, rules, road alignment, and utility corridors. GIS also helps ensure that buildings do not encroach on public land or utility lines, improving accuracy and speeding up building permission approvals.

GIS can spatially identify designated growth nodes, industrial corridors, and special economic zones within a regional development plan. By integrating regulatory layers such as zoning, environmental constraints, and infrastructure capacity, GIS ensures that project approvals align with planned growth areas. This reduces haphazard expansion and promotes balanced regional development.

GIS allows authorities to map zoning categories and Floor Area Ratio (FAR) norms across the city. By linking this data with property tax databases, officials can verify whether constructed building areas comply with approved FAR limits. GIS-based analysis helps detect under-assessed properties, unauthorized floor additions, or land-use changes, thereby improving tax compliance and revenue collection.

The Municipal Corporation of Delhi (MCD) strengthened governance through the implementation of a GIS-based citizen portal powered by Esri India using ArcGIS. Earlier, MCD faced major challenges due to fragmented data systems, reliance on Excel sheets and paper-based workflows, and limited inter-departmental coordination. Data was confined within zones and wards, leading to uneven resource allocation, inconsistent budgeting, and weak strategic planning. The absence of structured visualization tools further restricted informed decision-making.

The new single-window GIS portal introduced a robust data model with seamless migration of legacy records, and accurate data publishing. Web applications and interactive dashboards now provide real-time insights for better monitoring of assets and services. A mobile app supports property tax surveys with geo-tagged data, while a Capital Project Plan application enhances infrastructure planning and resource optimization. Automated scripts and API integrations enable real-time updates, improving operational efficiency.

The platform supports services such as property tax management, trade licensing, birth and death registration, Swachhta Karamchari attendance, mosquito control monitoring, and public outreach. Overall, the GIS-enabled system has enhanced transparency, efficiency, and data-driven governance in Delhi.

Revenue Collection

Many urban local bodies struggle with limited financial resources due to low efficiency in property tax collection, inadequate user charges, and dependence on higher levels of government for funding. Poor revenue generation restricts investment in infrastructure, maintenance, and public services. Inefficient tax assessment systems and outdated property records further reduce municipal income, affecting long-term urban development and service delivery.

GIS supports revenue forecasting by analyzing property growth, land value patterns, and tax base expansion, helping municipalities plan sustainable finances.

ArcGIS provides a range of tools and capabilities that enable assessors to streamline their processes, improve accuracy, and make informed decisions, transforming how property assessments are conducted and property taxes are collected. It allows assessors to manage parcel data efficiently, including property boundaries, ownership information, and property characteristics. Parcel management tools facilitate the maintenance of accurate and up-to-date property records, ensuring fair and equitable assessments.

GIS supports property valuation processes by integrating spatial data with property characteristics and market trends. Assessors can perform comparative analysis, factor in location attributes, and assess the value of properties accurately. Tools like ArcGIS also aid in managing tax collection activities and generating reports on tax revenues and delinquencies. By visualizing tax collection data on maps and dashboards, assessors can prioritize collection efforts and identify areas requiring attention.

Integrated Designs

Inadequate planning and coordination result in fragmented infrastructure development, including roads, drainage, water supply, and public transport systems. Often, infrastructure is developed reactively rather than proactively, leading to congestion, flooding, and service gaps. The lack of integration between land use planning and infrastructure investment reduces efficiency and increases long-term maintenance costs.

GIS supports integrated urban designs by mapping population density, growth trends, and distribution patterns. By analyzing the spatial relationship between residential areas and public amenities such as schools, hospitals, parks, and transport hubs, planners can identify service gaps. This information guides corridor development, transit-oriented planning, and integrated township design to ensure adequate infrastructure and social amenities.

A Centralized Spatial Platform-Unlocking Several Benefits

GIS acts as a centralized spatial platform where approved layouts, development control regulations, environmental restrictions, and infrastructure plans can be integrated. This ensures coordination between planning departments, revenue departments, and service agencies. By maintaining a single source of spatial truth, GIS reduces conflicts, avoids duplication, and supports synchronized urban planning and implementation.

An Enterprise-Wide GIS application can aid Urban Local Bodies (ULBs) to manage the growing complexity of urban governance in an integrated, data-driven manner. As cities expand, multiple departments such as planning, engineering, revenue, water supply, sanitation, and transport generate large volumes of spatial data. An enterprise GIS platform brings all this information together into a single, centralized system, enabling coordinated planning, monitoring, and decision-making across departments.

A key advantage of an enterprise GIS is that it serves as a single gateway for all GIS information, applications, and maps. Instead of maintaining separate systems in different departments, the platform integrates cadastral data, infrastructure networks, land use maps, taxation records, and project information into one unified portal. This ensures data consistency, eliminates duplication, and improves accessibility for officials and policymakers.

Such systems also enable anytime, anywhere access through web-based and mobile GIS platforms. Field staff can update asset conditions, capture geo-tagged photographs, and monitor works in real time using mobile devices. Decision-makers can access dashboards and spatial reports remotely, improving responsiveness and administrative efficiency.
Enterprise GIS supports standardized GIS layers for all ULBs across a state, ensuring uniform data formats, projection systems, and attribute standards. This standardization allows seamless integration of data at the regional and state levels, facilitating better comparison, benchmarking, and coordinated development planning.

It also acts as a collaborative decision-support system, enabling multiple departments to analyze shared spatial data simultaneously. For example, planning, engineering, and revenue departments can collectively evaluate the impact of a new development proposal by overlaying zoning maps, infrastructure capacity, and tax records. This integrated approach reduces conflicts and improves policy coherence. An enterprise GIS significantly strengthens municipal finances by supporting revenue and expenditure monitoring. By linking property tax databases with spatial parcel maps, municipalities can identify unassessed properties, monitor tax collection efficiency, and forecast revenue growth. Similarly, expenditure on infrastructure projects can be spatially tracked, ensuring accountability and financial discipline.

Enterprise GIS also enhances work and project management by enabling geo-tagging of projects, tracking progress in real time, and monitoring timelines and budgets. This helps prevent delays, cost overruns, and duplication of work, while improving coordination among contractors and departments. Finally, enterprise GIS promotes transparency and accountability by providing public-facing dashboards and open data portals. Citizens can view approved layouts, infrastructure projects, and service coverage maps, thereby building trust and strengthening participatory governance.

The Municipal Corporation of Greater Mumbai, also known as Brihanmumbai Municipal Corporation (BMC), launched the OneMCGM GIS initiative to strengthen urban governance and improve citizen services across Mumbai.

OneMCGM is an integrated online geospatial platform that provides reliable, timely, and accurate location-based information and services to the public. It is helping BMC to be in a better position to service citizens, better monitor and control its operations, and introduce Customer Relationship Management (CRM) concepts, resulting in a tangible and visible increase in the quality of services for every citizen. The GIS portal, powered by Esri's ArcGIS, displays the latest information about various departments of the civic body, which could be mainly utilized by the officials and workers to speed up decision-making and coordination.

The initiative has improved transparency, reduced processing time, enhanced coordination, and enabled faster decision-making, ultimately delivering cost savings and better quality services to Mumbai's citizens.

Harnessing the various capabilities of Esri's ArcGIS, urban planners can create a central gateway for all GIS data, applications, maps, and users. Along with enabling department-wise geo-enabled workflows (Property Tax, SWM, Water, Roads, Disaster, TP), ArcGIS can provide web and mobile apps for inspections, complaints, project monitoring, and field data. It helps departments to achieve seamless coordination, reduced duplication, and faster governance decisions.

ArcGIS-enabled portals enable citizen reporting of issues, open data publishing, participatory surveys, and feedback, leading to active citizen involvement, transparency, and better policy acceptance. ArcGIS AI/ML and GeoAI tools can bring in intelligence and automation to urban planning and management. They can aid in automated encroachment detection, illegal waste dumping detection from imagery, building footprint extraction for property tax expansion, risk prediction—flood, heatwave, landslide using AI models. Such systems lead to early warnings, reduced manpower dependence, and predictive governance.

The Gurugram Metropolitan Development Authority (GMDA) implemented OneMap Gurugram, an enterprise-wide GIS platform developed on ArcGIS with support from Esri India, to enable integrated and evidence-based urban governance. GMDA faced major challenges due to fragmented datasets, incompatible data formats, inefficient inter-departmental coordination, and the absence of a unified decision-support system among multiple stakeholders, including municipal bodies and state agencies. These issues delayed development initiatives and limited informed planning.

To address this, GMDA established a centralized, GIS-integrated Decision Support System that serves as a collaborative platform for spatial and non-spatial data. OneMap Gurugram integrates land records, transport networks, telecom towers, water distribution, sewage and drainage systems, power infrastructure, public amenities, and environmental data into a federated architecture. The platform clusters GIS layers into department-specific applications, supports interactive dashboards for the Integrated Command and Control Centre, and enhances transparency and citizen engagement through its webGIS portal.

By providing updated datasets, real-time project visibility, and links to departmental applications, OneMap Gurugram improves coordination, accelerates decision-making, strengthens land acquisition and infrastructure planning, and promotes intelligent, map-based governance for sustainable urban development.

Living Digital Twins: Transforming Urban Development

Many city administrations are turning to real-time digital data to enhance service delivery, improve planning accuracy, and optimize decision-making. By integrating live data from sensors and monitoring systems, cities can create "what-if" scenarios to test infrastructure upgrades, environmental strategies, transport systems, and master plans before implementing them on the ground. This is where GIS-enabled Living Digital Twins are emerging as transformative tools for urban governance.

A Living Digital Twin is a dynamic, virtual replica of a city's physical systems. Powered by GIS, it integrates real-time data streams from diverse sources such as traffic management systems, SCADA-controlled utilities, environmental and weather sensors, surveillance feeds, and GPS-enabled public transport networks. These inputs combine to form a comprehensive, continuously updated digital model of the city. Unlike static maps or traditional planning documents, a Living Digital Twin evolves in real time, reflecting current conditions while enabling predictive analytics and scenario testing.

By bringing cities to life in the digital realm, Living Digital Twins empower urban local bodies to move from reactive management to proactive governance. They strengthen policy formulation, improve service efficiency, and enhance transparency by providing data-driven insights into urban performance. Ultimately, by integrating live data with geospatial intelligence, Living Digital Twins support smarter planning, responsive administration, and resilient urban development—maximizing long-term value for the communities they serve.

Conclusion

GIS plays a transformative role in strengthening urban governance by enabling data-driven decision-making, transparency, accountability, and efficient service delivery. In rapidly growing cities, managing complex urban systems requires accurate, real-time, and location-based information. GIS provides a unified platform where spatial and non-spatial data, related to land, infrastructure, utilities, population, environment, and public services, can be integrated, analyzed, and visualized for informed governance.

GIS transforms raw geographic data into actionable intelligence. By visualizing risk, modelling future conditions, and guiding infrastructure and policy decisions, GIS strengthens a community's ability to anticipate shocks, adapt to change, and recover effectively. Without location intelligence, resilience planning remains incomplete. With spatially intelligent planning, cities can move from reactive disaster response to proactive, data-driven resilience planning.

GIS supports resilient planning by integrating spatial data, infrastructure systems, and predictive modelling to help cities anticipate, withstand, and recover from disruptions. When integrated with new technologies, GIS becomes a powerful tool for enhancing infrastructure reliability, improving resource allocation, supporting real-time decision-making, and building adaptive, sustainable, and resilient cities.

CASE STUDY

ArcGIS Enabling Evidence-based Decision-making at Lucknow Development Authority

Client
Lucknow Development Authority

Industry
Urban

Project
Urban Vista Lucknow; A comprehensive GIS Portal

Organization Profile
The Lucknow Development Authority (LDA) is a statutory body established under the Uttar Pradesh Urban Planning and Development Act, 1973, tasked with planning and overseeing the city's structured development. Its mandate includes land acquisition and development, housing and infrastructure projects, enforcement of zoning and building regulations, and implementing the city's master plan. Its core functions include:

- Formulating and implementing the Master Plan for urban growth.
- Developing housing schemes and planned neighborhoods.
- Land acquisition and management.
- Infrastructure provisioning and public amenity creation.
- Enforcement of land-use and construction norms.

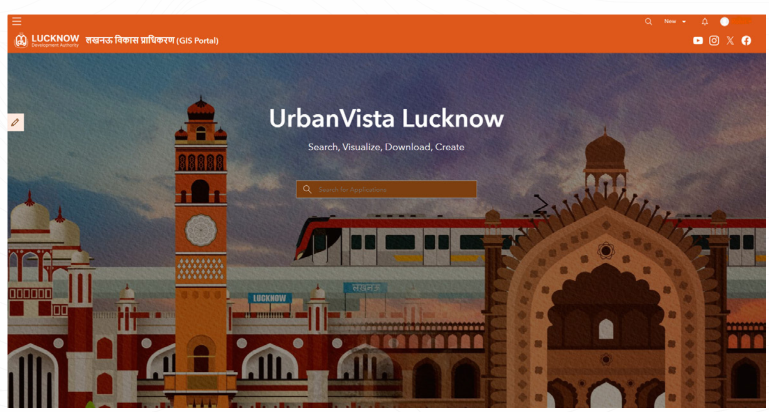
LDA works to balance sustainable urban growth, affordable housing, and civic infrastructure enhancement as Lucknow expands.

Website
www.ldalucknow.in

Project Summary
The GIS-based Governance Model used by Lucknow Development Authority is one of the best practices that highlights how the use GIS can lead to effective outcomes in urban planning, development and management.

Urban Vista Lucknow, built on ArcGIS technology (a leading geographic information system framework for mapping and spatial analysis) enables LDA planners, government officials, and the public to view, query, and access authoritative spatial data tied to land parcels, road networks, utilities, and city master plan maps. The system consolidates disparate land and planning information into a single, interactive GIS interface to support evidence-based decision making across urban planning functions. ArcGIS integrates spatial layers with attribute metadata to manage, analyze, and display urban development information.

The portal presents a synoptic view of existing landuse and the Master Plan of Lucknow. There are a series of Web Apps and maps pertaining to Cadastral Land, Property Allotment, Nazool land and Master Plan projects. It involves satellite image-based interpretation of landuse and change detection on plot layouts. There are also Mobile Apps for data collection about Projects and Nazool Land. There are also public apps, such as, for Parks and Monuments.



Challenges
Before GIS and digital mapping tools were integrated into its planning workflow, LDA faced several operational and governance challenges:

Fragmented Land and Planning Data: Landuse maps, land records, ownership details, zoning classifications, and infrastructure layouts were stored across multiple departments in LDA. There was no single system to view the data. This hampered quick, reliable access for planning and approvals. A single source of truth was missing.

Limited Transparency and Accessibility: Property buyers and applicants lacked access to verified land-use and master plan information online, leading to confusion and fraudulent transactions where plots were misrepresented (e.g., green belt/road land marketed as residential). The absence of an easy, authoritative land-use verification system fuelled disputes and mistrust.

Manual Processes and Inefficient Governance: Workflow processes, including land allotments, application tracking, map approvals, and NOC issuance, were largely manual or relied on ERP systems. This led to long waiting times (often months) for approvals, several office visits, and a lot of paperwork for applicants, bottlenecks, and inconsistent decision-making due to the lack of a centralized spatial context. These constraints increased administrative burden and lowered responsiveness in urban planning operations.

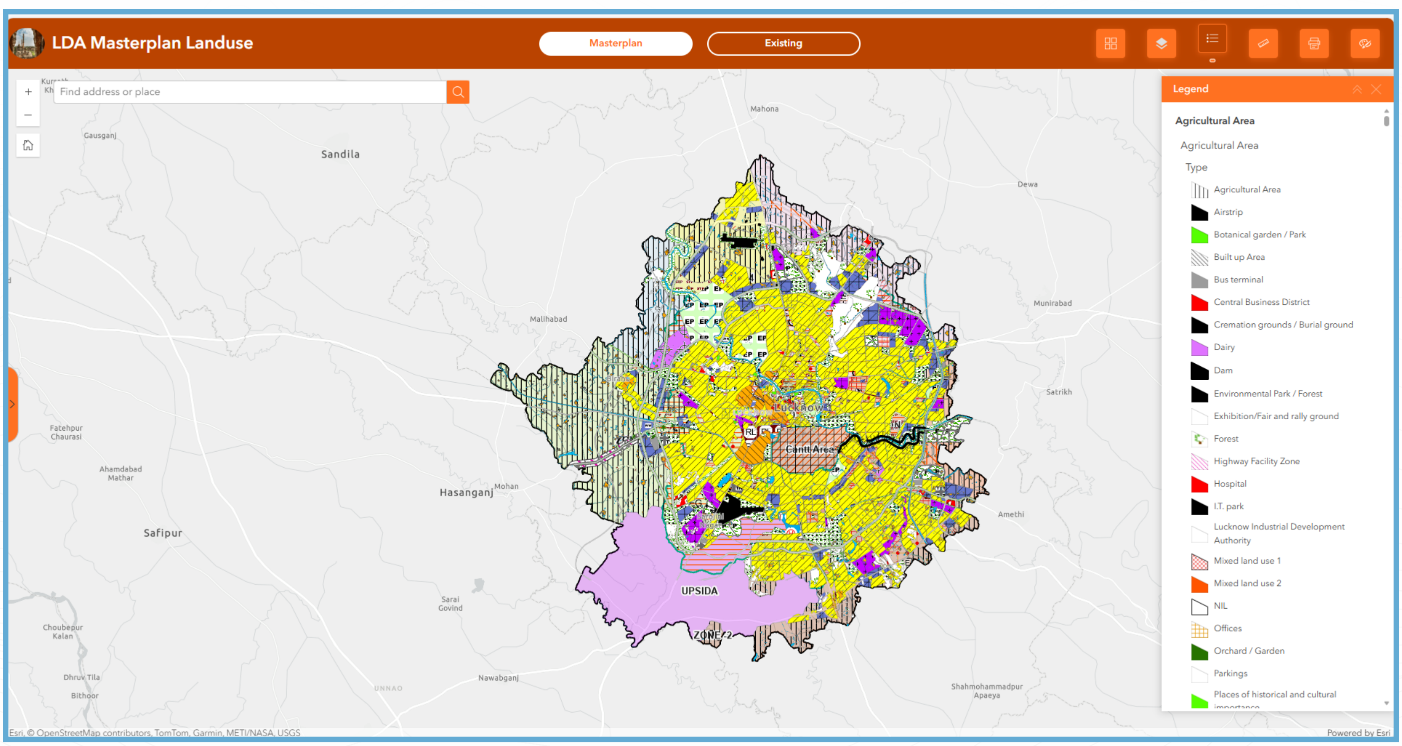
The Solution

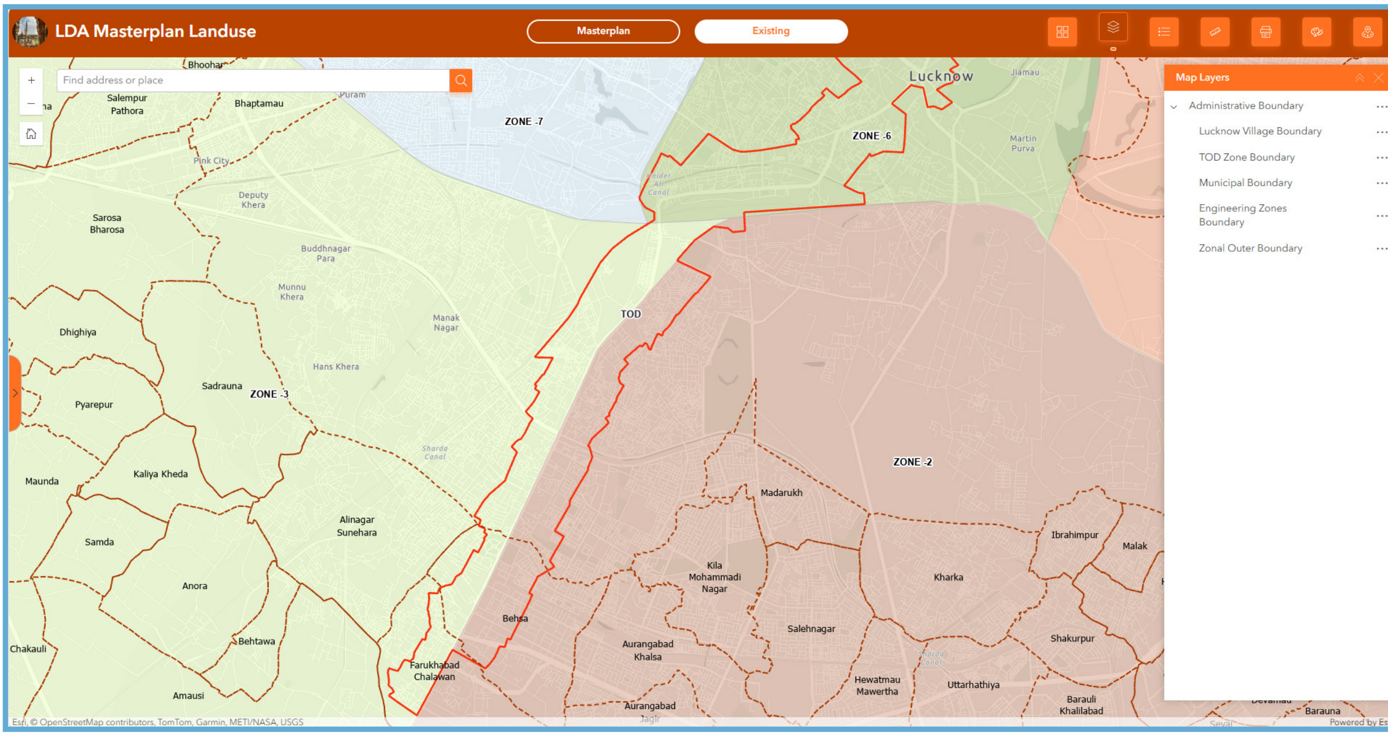
Esri India's holistic solution efficiently resolved the challenges faced by LDA through a single window-enabled GIS portal.

The following measures were taken to address the challenges:

Data Model Design: Implementation of a robust data model for structured data management and seamless integration with the existing ERP system for Property Status Update.

Data Publishing: Smooth transition of existing data from the conventional system of GIS to the Single Window Web GIS to bring the existing Landuse, Master Plan, Masterplan Projects, Nazool Land, Cadastral maps, all georeferenced at one single portal.





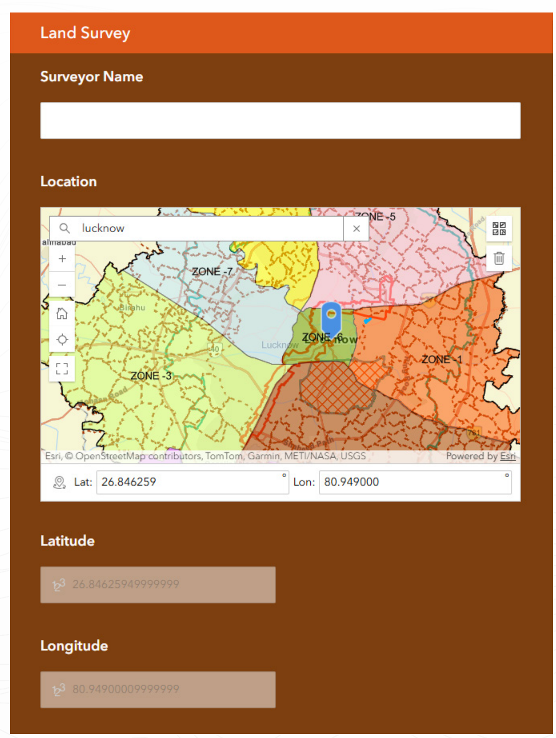
Data Preparation/Publishing: Facilitation of accurate data preparation and publishing, ensuring data reliability within the GIS framework.

Web Application Development: Creation of intuitive web applications for simplified access and visualization of geospatial data, streamlining monitoring and management of land use and assets of LDA.

Mobile App for Survey: Integration of a mobile application for Geotagging of projects and Nazool Land, enabling efficient data collection and real-time updates for urban management. Dashboards: Development of interactive dashboards offering stakeholders comprehensive insights and real-time updates on various operational aspects, fostering data-driven decision-making.

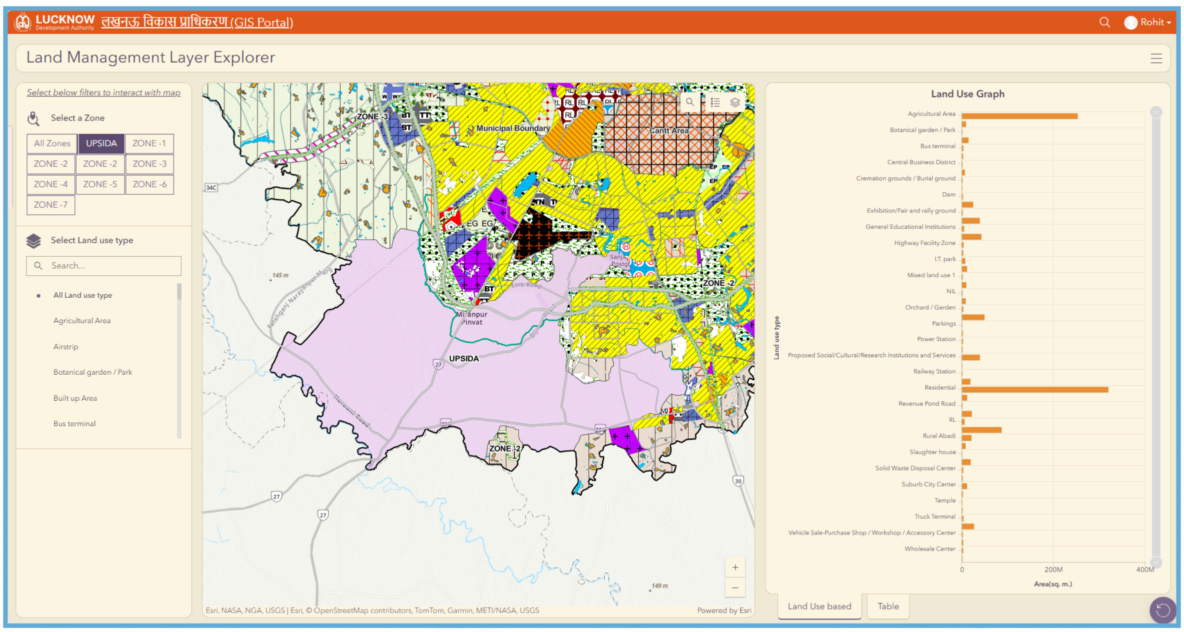
Integration with ERP: This includes integrating ERP APIs, enabling the department to embed property allotment data into Layout Files.

User-Level Training on Developed Applications: Conducting comprehensive training sessions for users to ensure proficiency in utilizing the newly developed applications, fostering self-sufficiency, and promoting the widespread adoption of the GIS platform within the organization.

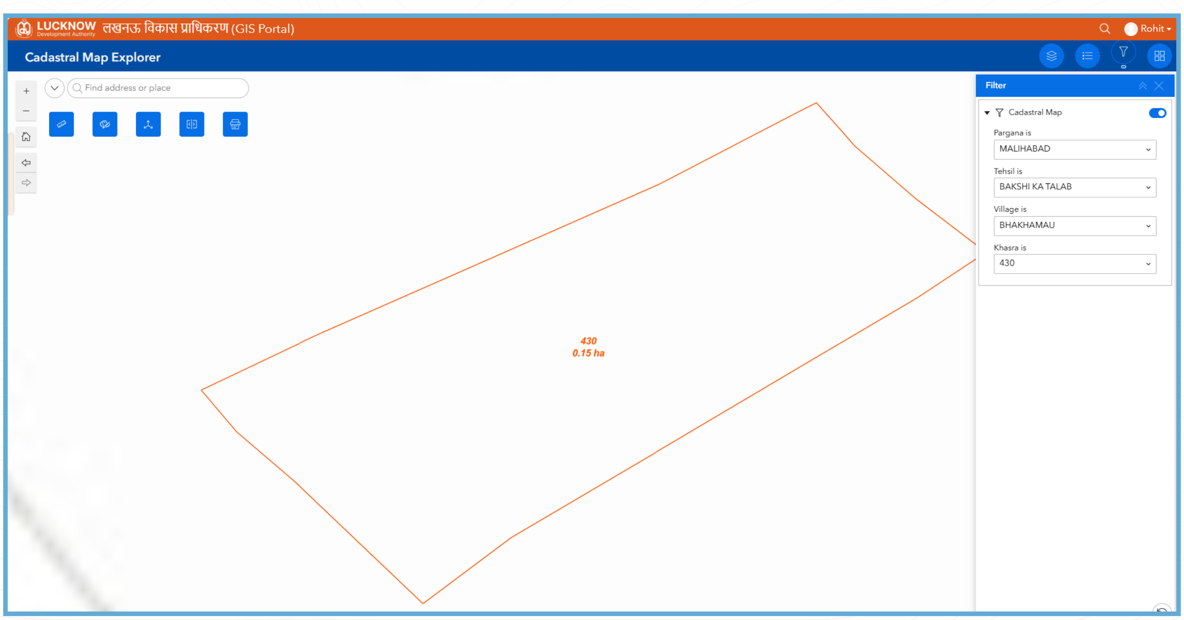


The solution includes a suite of web applications:

- Land Management Layer Explorer, a Dashboard for selecting types of landuse in different zones.
- Cadastral Map Explorer with the query to filter out individual parcel-level details.
- Sector Explorer with Integration with Property ERP for updated data about the plots.
- Nazool Land Explorer with maps of Nazool land published on the Web App.
- Park Locator for Parks under LDA.
- Monument Explorer with details of historical monuments in Lucknow, projects in LDA with geotagging, and the details of each project undertaken in Lucknow by LDA.
- Imagery Web Apps involving change detection through WayBack Imageries of Esri, whereby the Changes in Layout Maps over the years can be visualized.
- Sentinel 2 Land Cover Explorer showing the urban growth of Lucknow over the years.

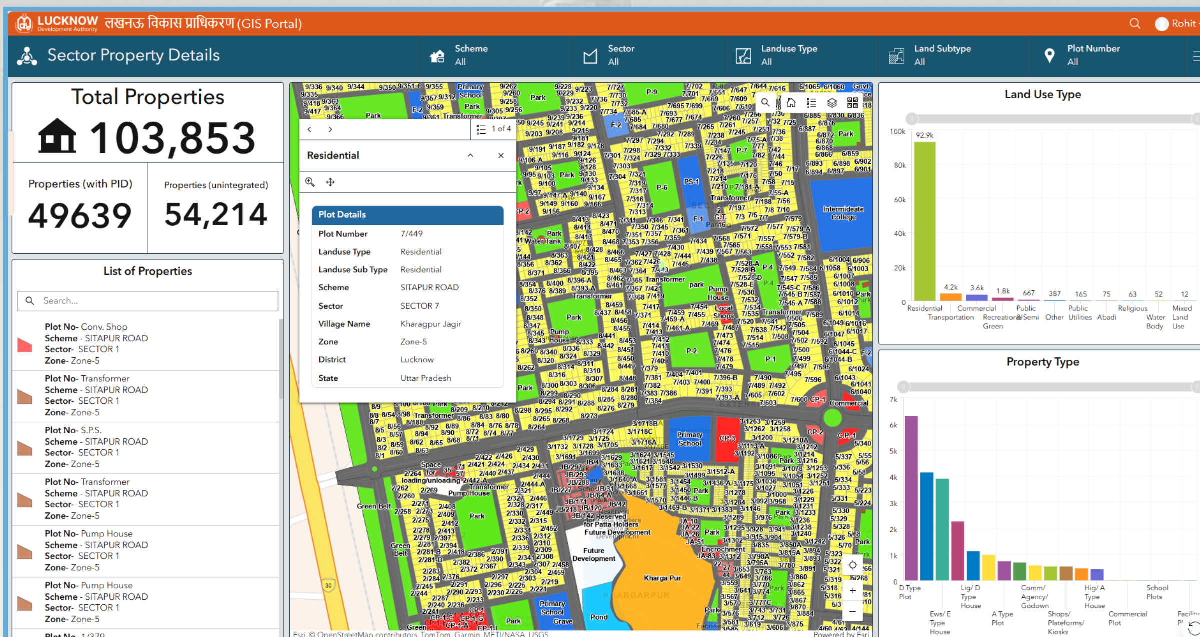


Land Management Explorer

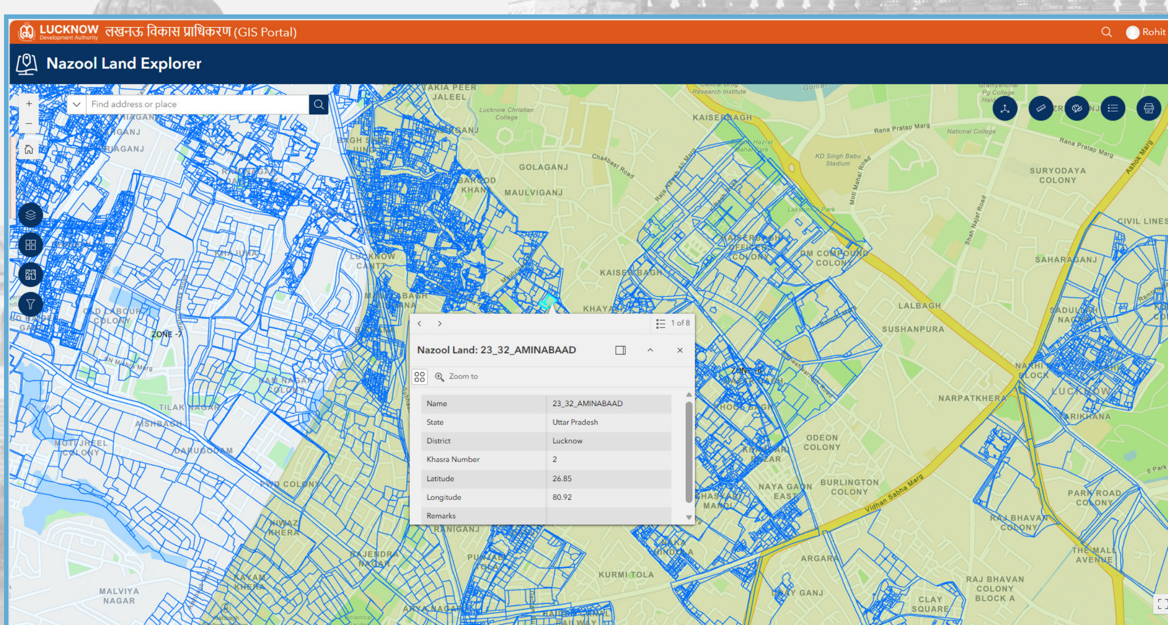


Cadastral Map Explorer

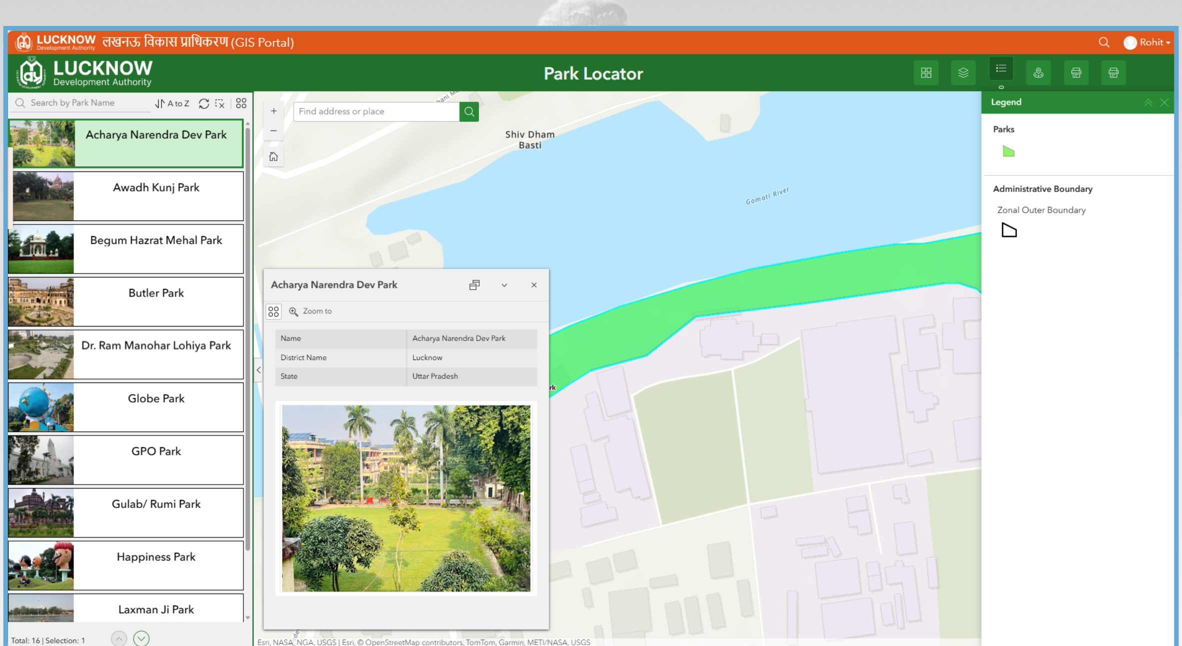
CASE STUDY



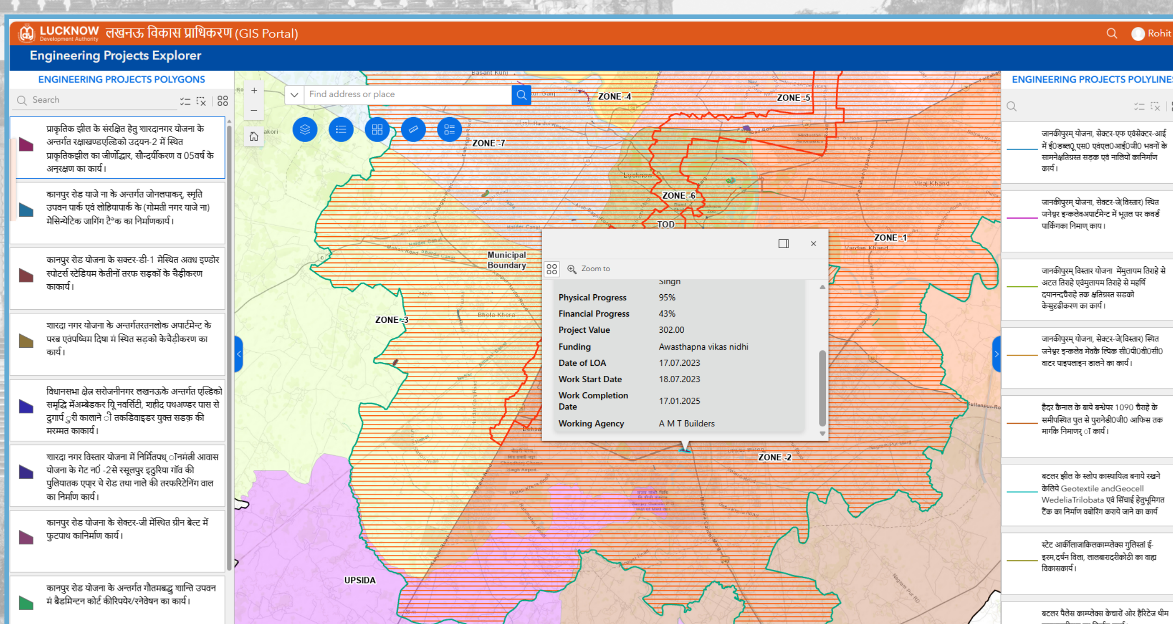
Sector Explorer



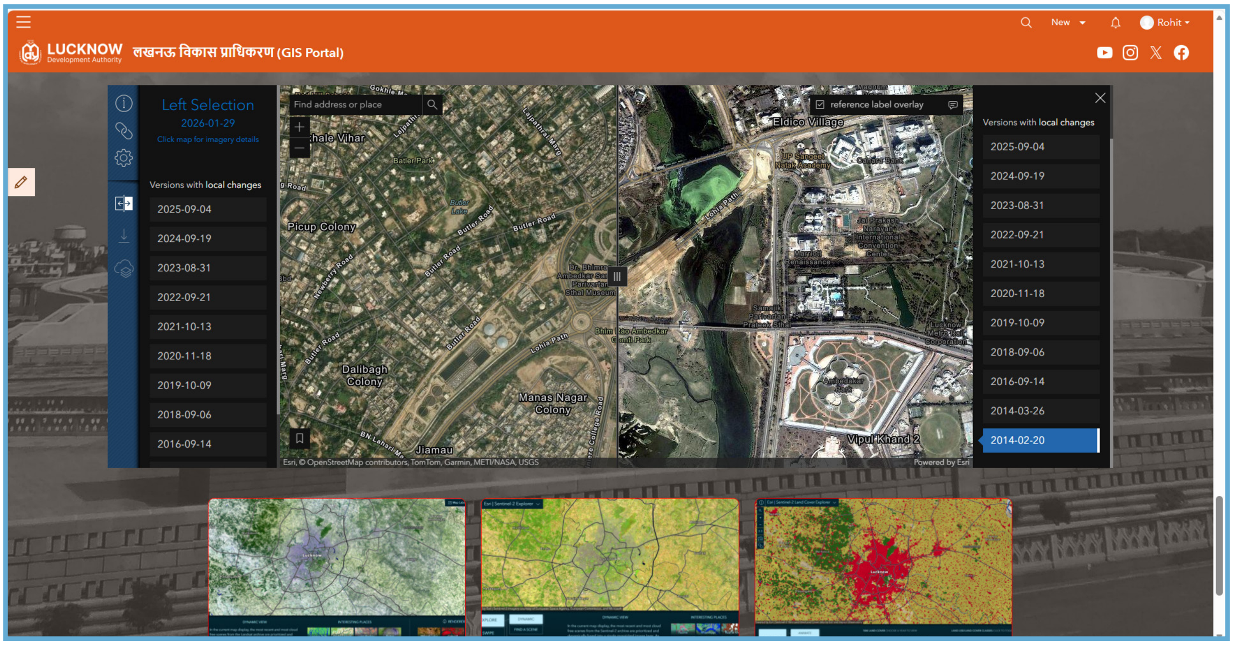
Nazool Land Explorer



Park Locator



Engineering Projects Explorer



Change Detection

These web applications have collectively contributed to the overall efficiency and transparency of the LDA's operations, promoting enhanced service delivery and streamlined administrative processes. They have enabled LDA to expand public outreach capabilities and gain a comprehensive visualization of existing landuse and Master Plan landuses on a single platform.

Benefits

Visualization of LDA's Planning, Engineering, Lands, and Properties data: The GIS solution enables visualization of LDA's planning, engineering, land, and property data in a single location, with metadata on a comprehensive GIS map, incorporating essential geodata for enhanced spatial analysis and informed decision-making.

Integration with Online Applications: The system's integration with various online applications enables the display of thematic maps, providing updated status information for projects in LDA, ensuring transparency and streamlined workflows. The integration with ERP ensures that updated information on the properties allotted by LDA is continuously available.

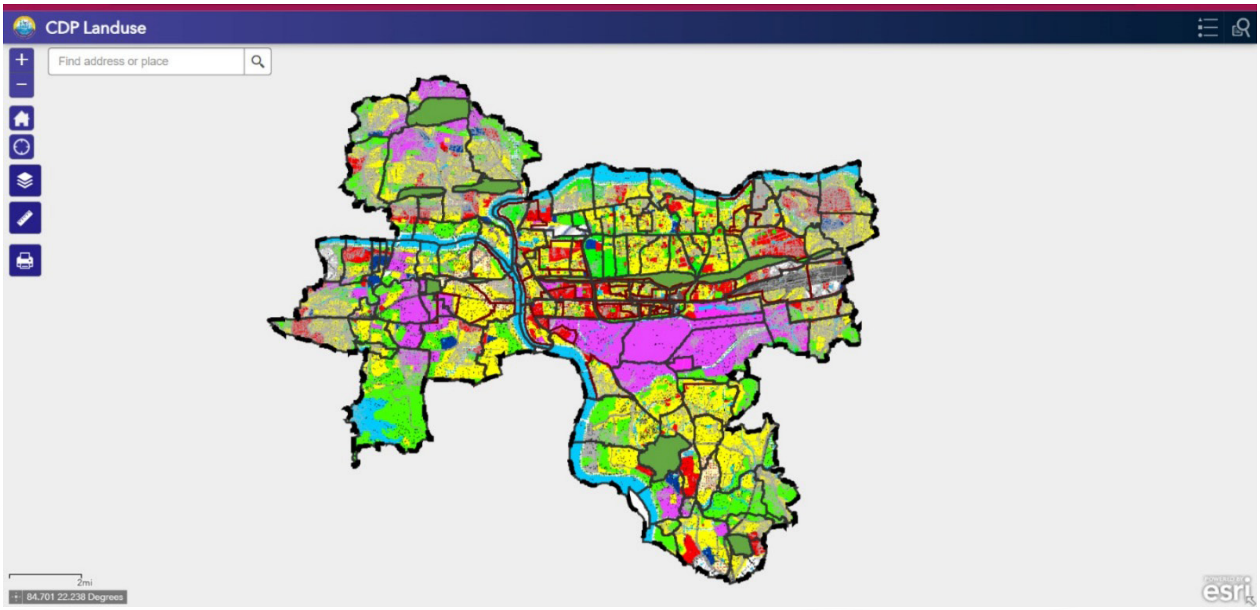
Simplified Information Management: The GIS tool simplifies the overall process of compiling, handling, manipulating, interpreting, and distributing information for the department, fostering improved data management and operational efficiency.

Enhanced Communication and Decision-Making: The strengthened communication and decision-making systems facilitated by the GIS solution promote better collaboration among stakeholders, leading to more informed and effective decision-making processes within the LDA.

Streamlined Resource Management: The sourced information through the GIS platform significantly eases day-to-day resource management, providing valuable insights for efficient resource allocation and utilization, thereby improving operational efficacy and resource optimization.

> Urban Vista Lucknow, built on ArcGIS, has helped us to bring land, infrastructure, and planning intelligence together on a single platform. This, in turn, has enabled transparent, data-driven decisions across urban planning functions within LDA.
>
> **- Shri. Prathamesh Kumar, IAS, Vice Chairman, Lucknow Development Authority**

A Collaborative GIS-Based Urban Management Solution for Rourkela Municipal Corporation



Emitech Infosystems Pvt. Ltd. collaborated with Esri India to deploy a GIS-based solution for the Rourkela Municipal Corporation (RMC). The solution aimed at improving urban management through streamlined data collection, visualization, and analysis. It focused on leveraging GIS for addressing urban challenges and empowering municipal authorities with robust tools for sustainable development.

GIS-based Building Information Management System

The system creates a single, geo-referenced digital record of all buildings in the city, where physical attributes, ownership details, land use, approvals, and compliance data are linked directly to their spatial location. This allows the municipal officials to move away from fragmented paper records and work with an integrated map-based view of the city, making information easier to access, verify, and update. As a result, building permits and development approvals become faster and more transparent, since zoning regulations, floor area ratios, setbacks, and height restrictions can be checked instantly against mapped data, while unauthorized constructions can be identified more efficiently.

The system is also significantly helping in improving disaster preparedness and emergency response by enabling authorities to quickly locate vulnerable or high-risk buildings, critical facilities like hospitals and schools, and optimal access routes during fires, floods, or earthquakes. When building information is linked with utility networks such as water supply, sewerage, electricity, and roads, municipalities can plan maintenance more proactively, reduce service disruptions, and manage infrastructure assets more effectively.

The GIS-based building information management system also strengthens property tax assessment by accurately capturing building footprints, usage, and expansions, helping identify under-assessed or unregistered properties and thereby increasing municipal revenue without raising tax rates. It streamlines property management by integrating mobile geospatial survey tools with a centralized administrative dashboard for data-driven oversight. It bridges the gap between field-level building data collection and real-time financial and analytical reporting.

In urban planning and governance, the GIS-based Building Information Management supports data-driven decisions on density control, land-use optimization, environmental sustainability, and climate resilience. It also enhances transparency and citizen services by enabling public access to building permits, landuse plans, and property information through the portal, thereby improving accountability and trust in municipal administration.

Modules

The various modules in the application include:

1. **Data Collection (Mobile Focus):** This module is built for capturing and modifying spatial and descriptive information directly from the field:

    a. **Edit Polygon:** Allows users to define or adjust the geographical boundaries and shapes of building plots.

    b. **Survey Data Collection:** Facilitates the systematic gathering of building-specific information through structured surveys.

2. **Admin Dashboard (Management Focus):** The dashboard provides administrators with tools to monitor operations and analyze collected data:

    a. **View Data Analytics:** Offers a centralized view of processed information to identify trends and metrics.

    b. **Plot-wise data viewer:** Enables detailed inspection of information organized by specific building plots.

    c. **Payment Collection Information Management:** Oversees the financial side of the building management process, tracking and managing payment data.

Through these modules and more, the **GIS-based Building Information Management System** is enabling RMC to deliver more efficient services, improve regulatory enforcement, strengthen financial management, and plan safer and more sustainable cities.

Transforming Urban Construction in Kerala through GIS-Driven Systems

To build safe cities, urban planning authorities must ensure that development activities comply with zoning regulations, building codes, and safety standards. The building permit process in urban administration ensures this compliance. GIS plays an important role in improving the efficiency and transparency of the building permit process.

In Kerala, this process, along with others, has been modernized through K-SMART (Kerala Solutions for Managing Administrative Reformation and Transformation), a digital governance platform developed by the Information Kerala Mission for local self-government institutions.

Let's explore more about the benefits of the K-SMART GIS application through an interaction with **Dr. Santhosh Babu IAS (VRS), Principal Secretary, MD-KSITIL & KFON, CMD & ED-IKM, Head-WNH Project, Vice-Chairman-CMD, Government of Kerala.**

What is K-SMART?

KSMART (Kerala Solutions for Managing Administrative Reformation and Transformation) is a data-centric solution that aims to enable smart e-governance for all local bodies, ensuring good governance for citizens. It has been developed by the Information Kerala Mission (IKM). Since Jan 2024, all Urban Local Bodies, and since April 2025, all Rural Local Bodies, run on K-SMART. All 1200 local bodies in Kerala run entirely on K-SMART.

What are the major benefits that this application is offering?

The platform is designed to eliminate manual intervention and expedite the building permit process, enabling easier, more transparent, faster services for citizens. The Building Permit (BP) Module is developed on ArcGIS.

The application offers the following benefits, mainly:

Instant Land Evaluation - "Know Your Land": Citizens can identify restrictions on their land, such as Coastal Regulation Zones (CRZ), railway, airport, high-tension lines, or eco-sensitive zones, using GIS mapping.

Automated Scrutiny: The GIS and e-DCR rule engines automatically verify building plans against regulations, accelerating the approval process.

Transparency and Access: Enables online submission and tracking of applications, reducing the need for physical visits to local offices.

Detailed Site Info: Provides specific data on permissible building height, mandatory setbacks, and land-use zones. Digital Convenience: Features include video call-enabled KYC, online fee payment, and the ability to download approved permits digitally.

"Issued Permit Map": Allows the public to view nearby issued building permits, ensuring accountability and preventing illegal constructions.

The K-Map in K-SMART enables citizens to verify details about constructions coming up in their neighbourhood. It ensures relatively easy-to-operate procedures for preparing drawings for rule scrutiny. It enables 100% system-generated scrutiny with no possibility of human intervention at the back end.

How has the K-SMART GIS application improved the speed, transparency, and reliability of services delivered to citizens?

K-SMART has significantly transformed local governance in Kerala by integrating 35+ modules into a single, unified, and digital platform based on microservices architecture and Devops engineering. By shifting from fragmented, paper-based workflows to a data-centric, mobile-based approach, it has dramatically improved the speed, transparency, and reliability of services for citizens, businesses, and expatriates.

Improved Speed of Services: K-SMART has reduced service delivery times from days to hours, or even seconds, for many critical services. For low-risk residential buildings (under 10m height/330 sq.m area), building permits are issued in under 10 seconds through an automated, paperless, and GIS-enabled e-DCR (Electronic Data Collection and Reporting) engine.

Enhanced Transparency: By allowing direct, digital applications, the platform removes the need for intermediaries.

Increased Reliability and Accuracy: The integration of GIS and spatial data has made the services more reliable and data-driven. Using the "Know Your Land" feature, citizens can instantly check spatial regulations (Coastal Regulation Zone, Airport/Railway Zones, etc.) for any plot using GIS, reducing the risk of unauthorized or problematic construction.

Uniformity in Decisions: The system uses uniform, automated rules for processing, reducing human error and discretion, ensuring consistent service delivery.

24/7 Access: Citizens can submit applications or complaints at any time, including weekends and holidays.

Secure Data Storage: K-SMART provides a secure, centralized digital repository for documents, ensuring they are not lost or tampered with.

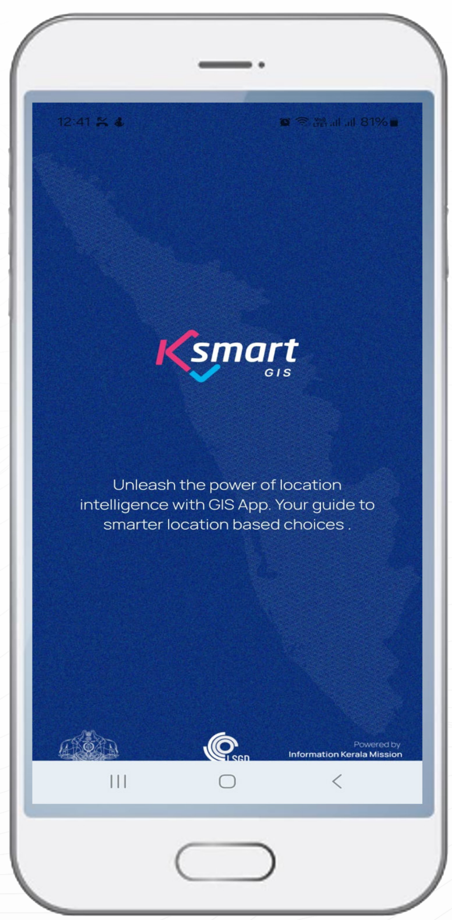
WhatsApp/SMS Integration: Keeps citizens informed on the status of their requests.

Through these advancements, K-SMART has enabled a "paperless" and "contactless" interaction with local bodies, significantly improving the overall citizen experience in Kerala.

What new capabilities are planned for K-SMART?

K-Smart is planned to be integrated with multiple systems to enhance data accuracy, service delivery, and decision-making. Integration with the Property Tax Module will enable geo-referencing of all individual properties, ensure accurate building identification, improve efficiency in tax collection, and support auto-generated unique building numbering. Through integration with the Public Grievance System module, grievance case locations will be geo-referenced, allowing authorities to make better-informed decisions based on the spatial distribution of reported issues. Integration with hazard mapping systems–covering flood-prone, landslide-prone, and drought-stricken areas will facilitate effective coordination of relief activities and ensure accurate dissemination of compensations. Additionally, integration with the Disease Outbreak Declaring System will support the timely dissemination of information on deceased cases and treatment status, enabling quicker response and improved public health management. A Digi Doorpin module based on GIS is also on the anvil on the K-SMART platform.

e-Governance is old school. K-SMART is our initial step towards adopting s-Governance or Spatial Governance, a-Governance or Algo Governance, and P-Governance or Predictive Governance.



ARTICLE

Living Digital Twins for Urban Development

By Rajesh C. Mathur, Senior Director - Strategy, Esri India

Digital Twins are virtual replicas of physical systems that enable real-time monitoring, simulation, and optimization across various domains. By integrating data from sensors, IoT devices, and analytical models, Digital Twins provide a dynamic interface for understanding and managing complex systems. A key advancement in this field is the incorporation of Geographic Information Systems (GIS), which enhances spatial awareness and contextual intelligence.

GIS-enabled Digital Twins not only visualize assets in their geographic context but also support predictive analytics and scenario modelling. Geospatial Digital Twins bridge physical and digital worlds, transforming raw spatial data into actionable insights for industries ranging from utilities to urban governance. By integrating GIS, IoT sensors, and AI, these models mirror real-world systems such as cities, utility networks, building interiors, and natural landscapes with precise spatial context.

What are Living Digital Twins?

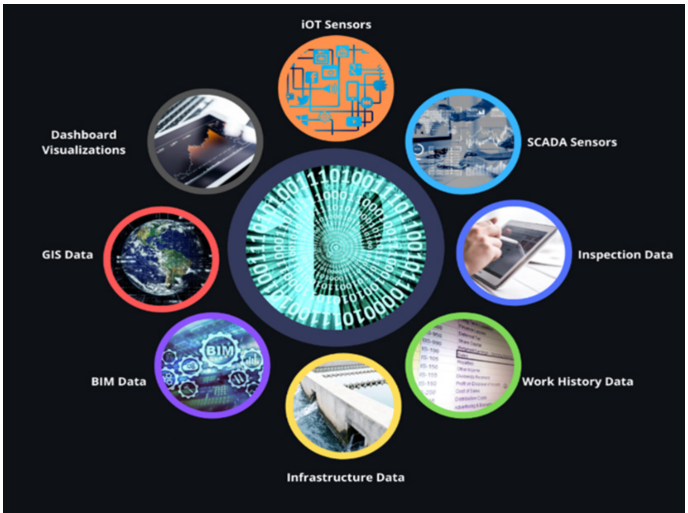
A Living Digital Twin is more than a 3D model or a simulation. It is a dynamic, continuously updated virtual replica of a city that integrates real-time data from sensors, CCTV cameras, IoT devices, satellite imagery, GIS platforms, Drones, LiDAR, BIM, and administrative systems. Unlike static digital models, a Living Digital Twin evolves with the city, enabling evidence-based planning, simulation, and governance. It is powered by a continuous flow of data and AI-driven analytics. **The living aspect allows the virtual model to mirror the exact state and behavior of its real-world counterpart at any given moment.** By integrating historical data and predictive modelling, Living Digital Twins can forecast failures before they occur. They are essential for managing complex systems like smart cities, utilities, disasters, the environment, manufacturing plants, and personalized healthcare.

Living Digital Twins Revolutionizing Urban Development

Urbanization across the world, including in India, continues to grow. It is estimated that 40% of the Indian population will live in urban areas by 2030. As urban populations swell and infrastructure systems become increasingly complex, traditional planning methodologies struggle to keep pace with the dynamic nature of modern cities. Urban local bodies are under immense pressure to improve resource allocation and city management. Traditional planning tools, although effective in certain scenarios, often fall short in predicting dynamic urban challenges.

There is a growing recognition among urban local bodies of the value of leveraging real-time digital data for monitoring the performance of existing citizen services, improving city planning, and optimizing decision-making. By ingesting real-time data, fed by sensors, one can create what if scenarios for amenities, infrastructure, environment, and master plans before real-world implementation. Enter GIS-enabled Living Digital Twins that promise to revolutionize the conceptualization, design, and management of urban environments.

These virtual replicas of physical urban systems integrate real-time data streams from multiple sources, including traffic data, SCADA, and sensors on utility networks, camera feeds, environment or weather sensor data, and Global Positioning Devices on public transportation systems, creating comprehensive models that enable predictive analysis and scenario testing. **Living Digital Twins bring cities to life in the digital realm, continuously mirroring the real-world conditions through live data.**



Relating Data to a Digital Twin

A digital twin can not only strengthen policy formulation and service improvement but also enable urban local bodies to demonstrate more responsive and agile governance that can ultimately maximize impact and value to the communities they serve. By integrating live data, they support smarter planning, proactive governance, and more resilient urban development.

How Digital Twins Can Impact Urban Transformation

Urban Planning: Digital Twins create virtual models of proposed development plans – roads, buildings, green areas, public transport, amenities like schools, healthcare centers, recreation facilities, utilities, etc., and evaluate the impact on traffic, environment, public utilities, et al, before physical implementation. They support data-driven decision-making for sustainable growth.

In Indian cities, characterized by rapid growth and complex land-use patterns, Living Digital Twins play a critical role in urban planning. They enable planners to visualize and simulate master plans, zoning regulations, Floor Area Ratio (FAR) changes, and redevelopment scenarios in three dimensions. Scenario-based simulations allow decision-makers to assess long-term consequences before implementation, reducing planning risks and improving spatial equity. Planners no longer need to depend on OD Surveys to identify traffic bottlenecks in cities; they are available in real-time over 3D models of cities.

Public Utilities & Infrastructure: Urban infrastructure systems such as water supply, sewerage, stormwater drainage systems, roads, and power networks are often managed in silos. Living Digital Twins integrate these assets into a common geospatial framework, enabling holistic infrastructure management. They enable predictive maintenance of roads, bridges, water, wastewater, and power utilities assets. **Real-time monitoring reduces downtime, improves asset life cycles, and reduces operational costs. Digital Twins enable utilities to monitor and optimize operations by capturing real-time data from sensors on water flow, pressure, and quality, among others.**

Digital Twins offer a transformative approach to managing complex utility systems with greater agility and sustainability.

Transportation and Mobility: Mobility is a real challenge for Indian cities. Living Digital Twins can enable cities to create a real-time, dynamic virtual model of roads, public transport, pedestrians, and freight movement, by integrating traffic sensors, GPS data, public transport systems, and geospatial analysis. They allow planners to simulate interventions such as signal optimization, new flyovers, and public transport reforms before implementation. This supports data-driven mobility planning, congestion reduction, improved safety, and a transition towards sustainable and inclusive urban transport systems. **Virtual testing of transport policies before on-ground implementation reduces costs and enhances public acceptance.**

Climate Resilience and Disaster Management: Indian cities are increasingly vulnerable to floods, air pollution, heatwaves, and extreme weather events. Living Digital Twins can play an enabling role in predicting floods and the development of mitigation strategies. They help in visualizing water flow, testing mitigation strategies, optimizing emergency response, and supporting infrastructure. Living Digital Twins integrate terrain models, drainage networks, weather forecasts, and environmental sensor data to strengthen climate resilience.

Applications include:

- o Urban flood modelling and early warning systems
- o Heat island mapping and mitigation planning
- o Air pollution monitoring
- o Emergency response and evacuation planning
- o Fire susceptible zones and evacuation planning

Governance and Citizen Engagement: Integrated Command and Control Centres (ICCCs) are the nerve centers of smart cities. Living Digital Twins provide a live, spatially accurate 2D/3D city view by integrating feeds from traffic systems, utilities, sensors, drones, and GIS, giving ICCC instant context and not just alerts. Living Digital Twins significantly enhance ICCC capabilities by providing spatial context, predictive analytics, and scenario visualization driven by live feeds.

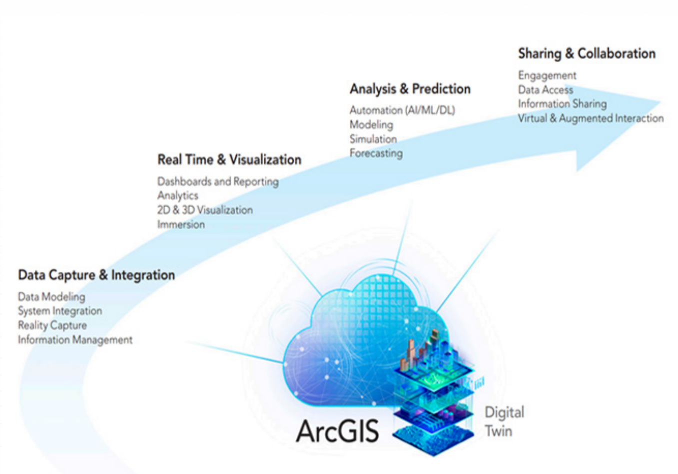
Digital Twins with live data inputs on GIS platforms help in taking effective decisions in ICCC, related to public safety, mission monitoring, crowd management in public events and large gatherings, analyzing vulnerable areas in the city, and taking appropriate decisions. GIS platforms enable all sensors to integrate into a single digital twin, rather than operate in silos with a lack of coordination in decision-making.

They enhance interdepartmental coordination, improve transparency, and citizen engagement through visualization and scenario-based decision support. Citizens can better understand urban projects and policies when they are visualized on a city-scale digital twin. Visualization through the digital twin improves briefing quality for leadership and builds citizen trust through clear, explainable decisions.

Safety and Security: Living Digital Twins support crime pattern analysis, hot spot mapping, crowd monitoring, and event security planning. By integrating camera feeds, traffic data, emergency response systems, and geospatial intelligence, they enable early detection of threats, predictive analysis, and faster multi-agency coordination, improving preparedness, response time, and citizen safety. Overall, Living Digital Twins shift urban safety systems from reactive response to predictive, coordinated, and resilient city security management.

ArcGIS for Digital Twins

A digital twin brings together many adjacent yet distinct worlds. Central to a Living Digital Twin is the 3D System, which provides clarity, new perspectives, and connectivity to foster sustainable workflows for complex and evolving challenges. ArcGIS empowers organizations to adopt and mature digital twin technologies by integrating real-time sensor data, AI/ML, and advanced analytics. It enables dynamic virtual models that are descriptive, informative, predictive, and autonomous—supporting scenario-based simulations, remote inspections, and adaptive decision-making. With 2D/3D visualizations and IoT integration, ArcGIS transforms physical assets into intelligent, connected systems for enhanced operational efficiency. ArcGIS-based digital twins enable remote inspections and adaptive operations, helping organizations transition from static representations to intelligent, self-learning systems. This comprehensive approach empowers city administrators to optimize performance, enhance situational awareness, and drive smarter, data-driven decisions.



Way Forward

Living Digital Twins represent the next evolution of urban development in India –from reactive monitoring to predictive and adaptive urban management. With the enabling framework of the National Geospatial Policy 2022, Indian cities have a unique opportunity to institutionalize Living Digital Twins as core digital public infrastructure. To realize this potential, cities must focus on data governance, capacity building, interoperability standards, and sustained public-private collaboration. When implemented strategically, Living Digital Twins can become a cornerstone of resilient, inclusive, and future-ready urban development in India.

ArcGIS Velocity

A Dynamic Infrastructural Awareness

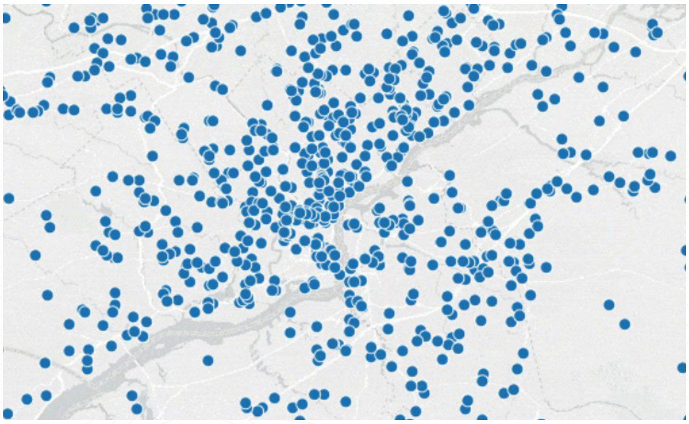
ArcGIS Velocity is Esri's cloud-native, software-as-a-service (SaaS) solution designed for real-time and big data processing and analysis capability of ArcGIS Online. Already embedded in the ArcGIS Online ecosystem, Velocity removes the traditional barriers of server management, allowing you to import, visualize, analyse, and use data from Internet of Things (IoT) sensors.

ArcGIS Velocity essentially combines the best of both GeoEvent Server (real-time processing) and GeoAnalytics Server (historical big data analysis) into a single, online hosted environment.

Key Features

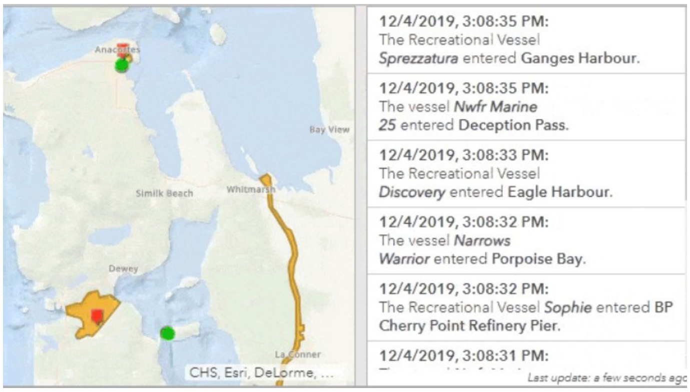
Integrate real-time data

Ingest data from connected devices by configuring a feed that can be used as a live map layer. Integrate real-time streaming, historic IoT data from multiple feeds, and visualize directly in maps with feature layers to analyze change over time. The highly scalable Kubernetes-based architecture of ArcGIS Velocity enables the processing of massive volumes of spatial data at very high speeds.



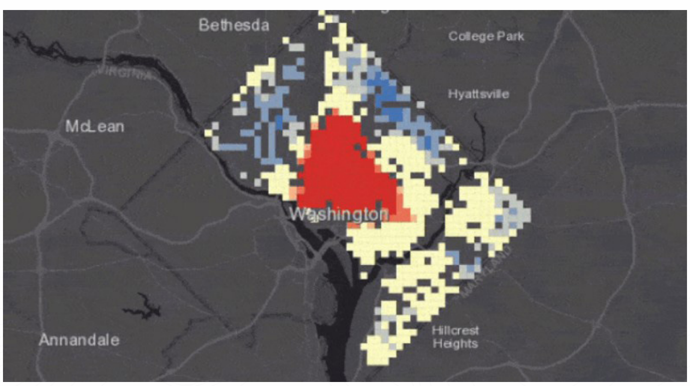
Monitor critical assets

Precise locations and insights are visible on all assets 24/7. In addition to that, dynamic assets can be tracked that are constantly changing location, such as vehicles, aircraft, vessels, and stationary assets, such as weather and environmental montoring sensors.



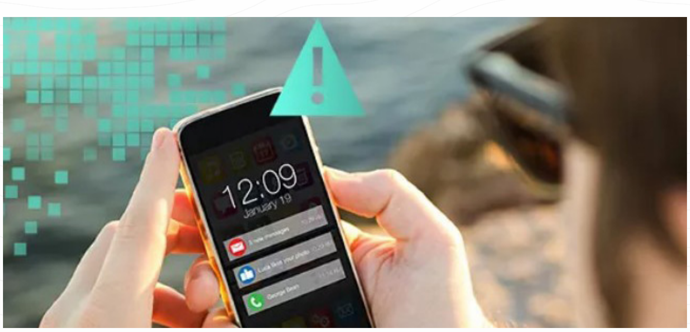
Unlock spatial insights

Informed decisions with IoT spatial intelligence analysis can be made with access to a range of powerful real-time and big data tools to analyse information from a variety of data feeds and sources. Identification of spatial relationships between features using dynamic geofencing can be done. Visual analytics model builder can be used to design complex analyses and automate workflows, thus saving time and effort.



Trigger alerts

Results from analytics, whether performed in real time or batch mode, can be pushed as alerts, which puts time-sensitive information in the hands of personnel. You can display and share the findings with others in the same organization with the help of operational dashboards. You gain operational, tactical, and strategic efficiencies that save time and money.



Work in the cloud

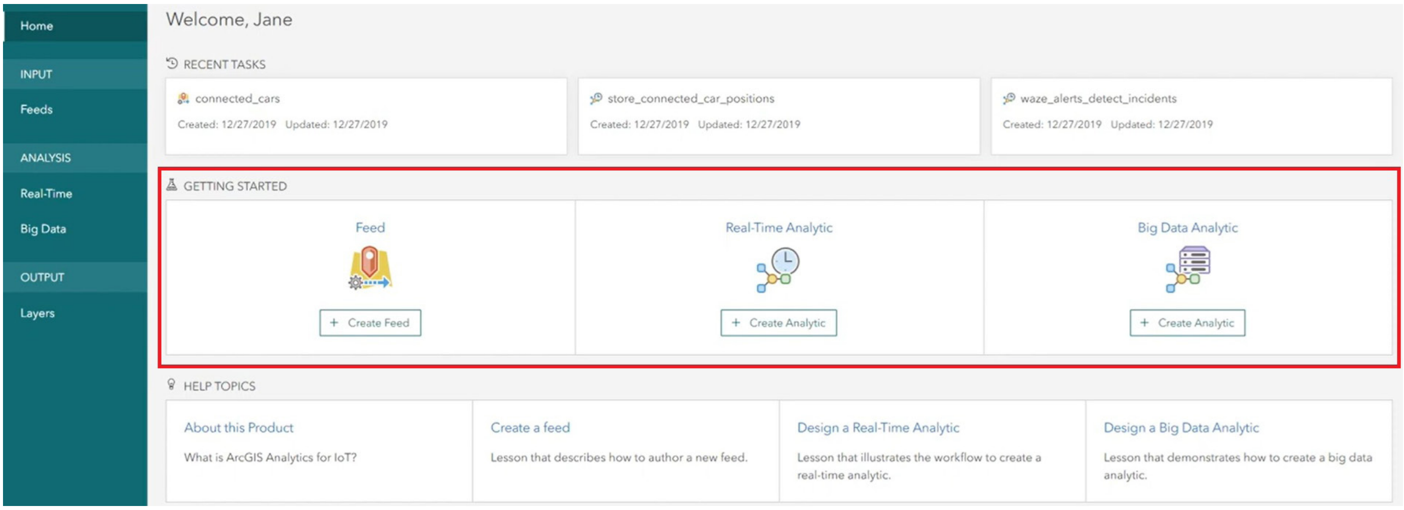
You can get started quickly with no configuration with a SaaS model. You can take advantage of distributed computing. You can get real-time and big data capabilities as a service and perform analytics at a massive scale.

This software as a service (SaaS) IoT application can better leverage your real-time spatial data for essential operational decisions such as remote monitoring of assets, predictive maintenance, preparedness, and process optimization.

Key Benefits

- **Improved Situational Awareness:** Provides a real-time "common operating picture," allowing organizations to monitor assets, personnel, and environmental conditions 24/7.
- **Faster Decision-Making:** Reduces the time from "observation to action" by automating the detection of critical events and notifying the right people instantly.
- **Operational Efficiency:** Automates repetitive monitoring tasks and allows for predictive maintenance by identifying potential issues before they cause failures.
- **No Infrastructure Management:** As a SaaS offering, there is no need to install, maintain, or scale servers. Esri manages the underlying cloud architecture, which scales automatically based on data volume.
- **Unified GIS Ecosystem:** Seamlessly integrates with the rest of the ArcGIS system (Dashboards, StoryMaps, Field Maps), allowing you to use real-time data across all existing spatial applications.

How it Works



i. **Connect and Create feed:** Connect to real-time, streaming IoT data from multiple feeds and visualize directly in maps once the feeds are active.

ii. **Analyse:** Speed up analysis and get answers faster when you set up analytical models in the cloud.

iii. **Alert and actuate:** Act with analysis by sharing the results and alert stakeholders when it matters.

Common Use Cases and Impact on Urban Infrastructure

1. ArcGIS Velocity ingests live traffic sensor data, GPS feeds from public transport, and traffic cameras.
   - o Real-time data ingestion from IoT devices
   - o Detect congestion, accidents, and bottlenecks
   - o Trigger alerts and dashboards for traffic authorities

Urban impact

» Reduced congestion
» Faster incident response
» Optimized signal timing

2. Monitoring water pipelines, power grids, and streetlights using sensor data.
   - o Stream analytics to detect pressure drops, outages, or abnormal readings
   - o Real-time alerts for maintenance teams

Urban impact

» Preventive maintenance
» Reduced downtime
» Improved service reliability

3. Real-time monitoring of rainfall, river levels, and weather data.
   - o Ingest live meteorological and sensor data
   - o Analyze thresholds and trigger alerts
   - o Feed results into web maps and dashboards

Urban impact

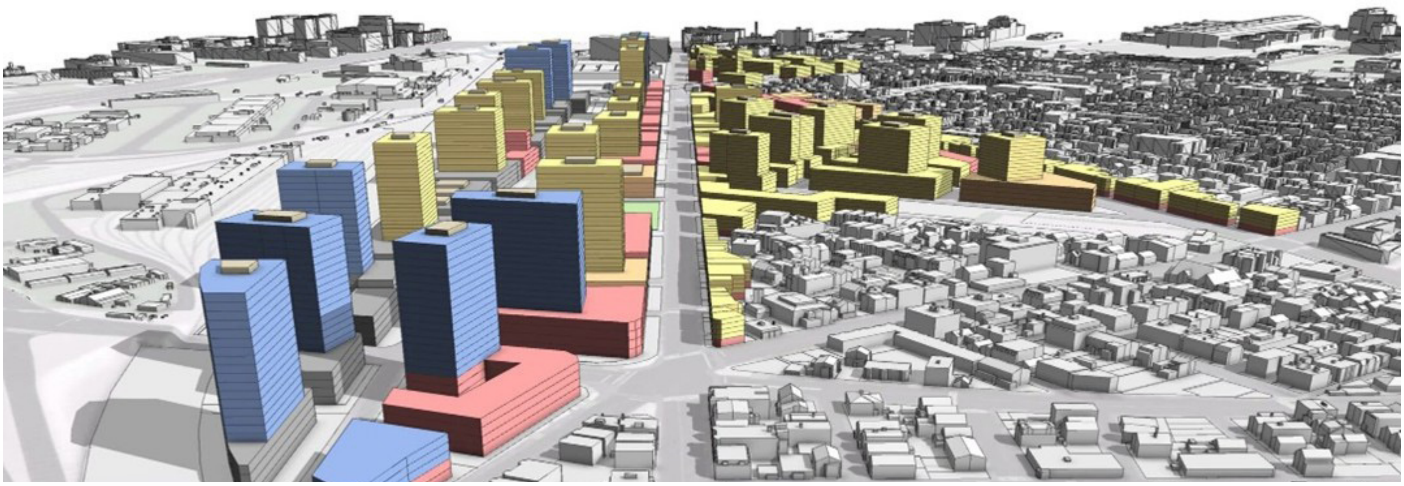
» Early warnings to citizens
» Better disaster preparation
» Reduced loss of life and property

4. Monitoring air pollution levels using real-time sensors across the city.
   - o Analyze streaming air quality data
   - o Detecting pollution spikes
   - o Support policy decisions and public advisories

Urban impact

» Health risk mitigation
» Environmental compliance
» Sustainable urban planning

CityEngine Adds a New Dimension to Your GIS



In the weeks since Esri announced the acquisition of Swiss company Procedural and its flagship product CityEngine, many users have been exploring how they could leverage this new product for their GIS work. The key functionality provided by CityEngine, high-end 3D content creation from simple 2D GIS data, is simple enough to understand.

Explore CityEngine in virtual reality

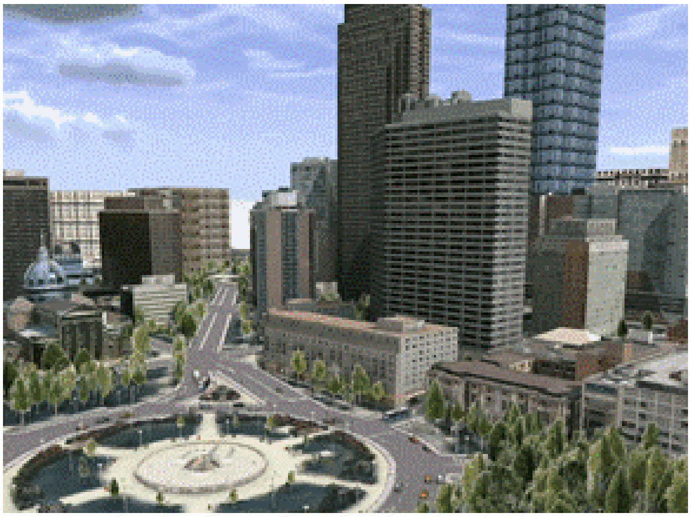
Explore CityEngine scenes and compare scenarios in virtual reality (VR) with the ArcGIS 360 VR web app in ArcGIS Online. Export CityEngine scenes and save bookmarks in CityEngine to allow navigation to camera views in VR. In the CityEngine app, click **File > Export 360 VR Experience** and select the scenarios to export.

Work with scenarios

Scenarios allow you to create multiple designs within a single scene and then compare them with each other. Dashboards are also scenario enabled and can show the values for multiple scenarios simultaneously, allowing you to compare design performance.

Measuring more than just distance in CityEngine

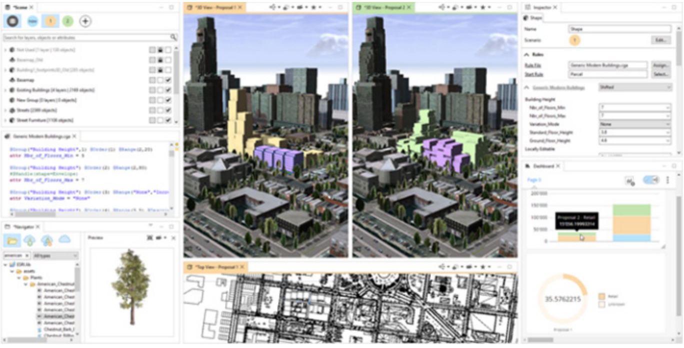
Using Measure features in CityEngine, planners and GIS professionals can go beyond visualization and perform quick spatial analysis directly in a 3D scene.



Trick: Measure first, model second: Measure block sizes, street widths, and parcel depths before applying CGA rules. Measure building heights, step-backs, and courtyard widths after rule execution.

Getting More Value from the CityEngine Toolbar

Tip: Keep geometry simple in early scenarios; focus on metrics first (height, density, open space), then add detail to the preferred option.

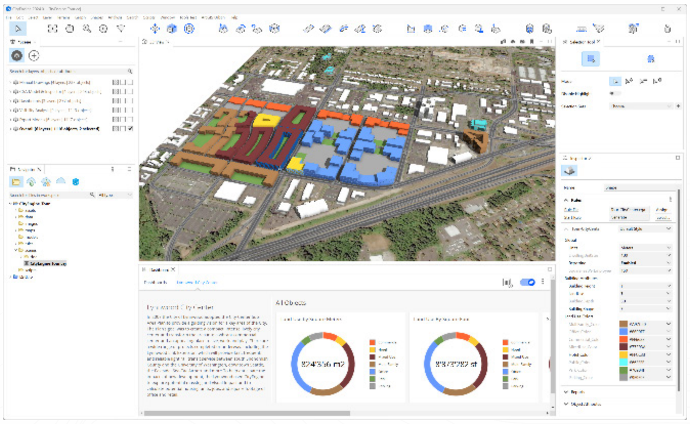


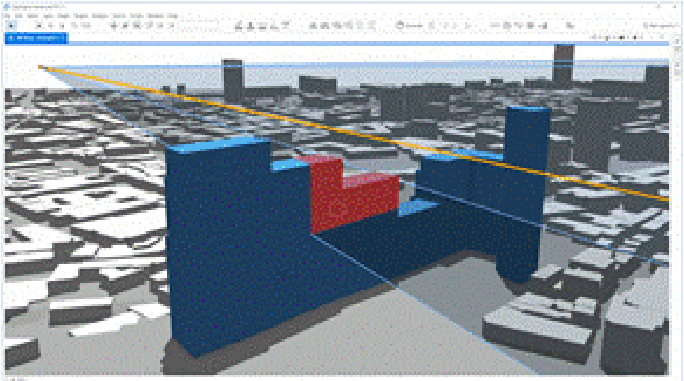
- Navigation tools:
  Trick: Use Frame Selection frequently when working with dense scenes
- Transform tools:
  Trick: Use numeric input for move, rotate, and scale instead of free dragging.
- Graph tools:
  Trick: Build street graphs early even before parcels.
- Terrain tools:
  Trick: Use Align Shapes to Terrain after importing GIS parcels.
- Analysis tools:
  Trick: Use Measure and Visibility Analysis during design reviews

Visibility analysis

The Visibility analysis tools display surfaces and structures that are visible and hidden from an observer.

Tip: The **Viewshed** tool shows visibility from a camera-like observer. With the **View Dome** tool, you can visualize visible and hidden areas from an omnidirectional observer. Finally, the **View Corridor** tool creates a protected view where any scenario building visible in the corridor is colored. Plus, you can view visibility statistics about your scene in **Inspector.**

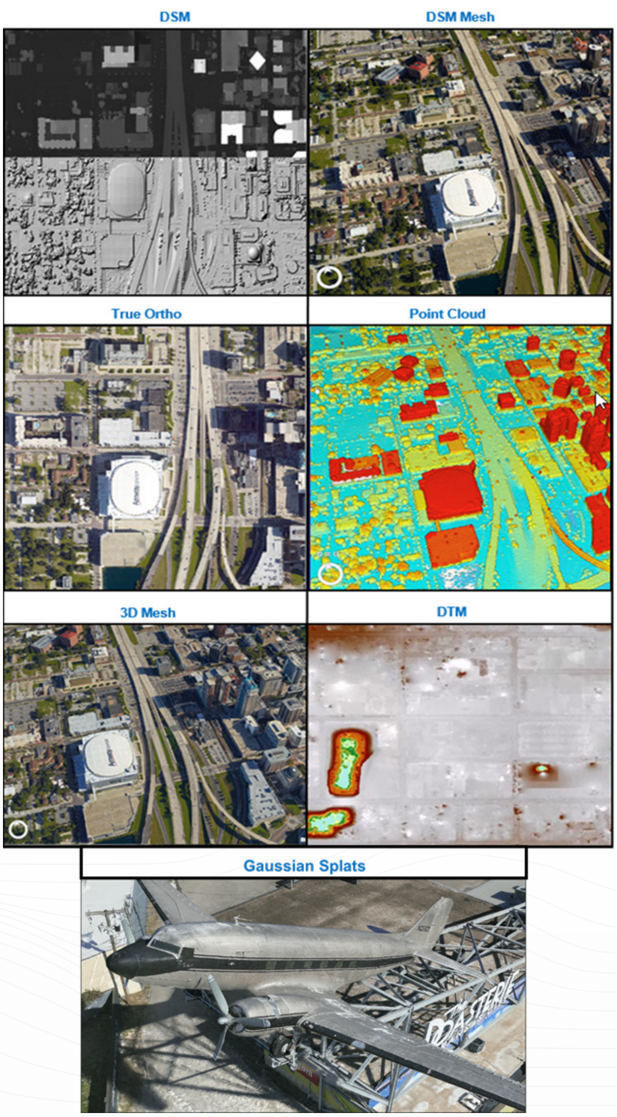




Used together, these tools form a repeatable workflow, navigate, draw, generate, analyze, and regenerate–supporting rapid design iteration.

ArcGIS Reality for Pro

ArcGIS Reality for ArcGIS Pro is an ArcGIS Pro extension that expands ortho mapping capabilities with high-fidelity 2D, 3D, and True Ortho product generation. ArcGIS Reality for ArcGIS Pro is enabled with an ArcGIS Pro Standard or Advanced license, together with an ArcGIS Reality license. When the ArcGIS Reality for ArcGIS Pro extension is enabled, you can generate the following products from drone and digital aerial imagery: Digital Surface Model (DSM), Digital Terrain Model (DTM), True Ortho, DSM Mesh, Point Cloud, 3D Mesh, Gaussian Splats.



What's New in ArcGIS Reality for Pro

Simplified Installation: ArcGIS Reality for ArcGIS Pro is installed as part of the ArcGIS Pro installation. ArcGIS Reality for ArcGIS Pro extension installation is no longer needed from ArcGIS Pro 3.6. This means that you only need to activate the extension license to start integrating Reality Mapping into your workflow.

Lidar Support for Derived Product Generation: You can now integrate aerial lidar with imagery when generating DSMs, True Orthos, DSM Meshes, and 3D Meshes for superior product quality—especially in urban environments, areas with reflective surfaces or street canyons where image coverage may be limited.

Expanded Satellite Support: ArcGIS Reality for ArcGIS Pro now supports the full constellation of Vantor's WorldView Legion satellites, giving users access to the next generation of very-high-resolution imagery, including up to 15 cm HD quality, directly within their workflows.

With this added support, organizations can seamlessly ingest, process, and analyze Legion imagery to generate high-fidelity 3D meshes, DSMs, and True Orthos for rapid situational awareness and global monitoring.

Gaussian Splats: This release introduces Gaussian splats, a new 3D layer generated from drone or aerial imagery. Gaussian splats excel at capturing fine-grained details of infrastructure, vegetation, and urban environments with exceptional fidelity, creating a more immersive GIS experience. Plus, you can generate Gaussian splats layers in your desired spatial reference, ensuring seamless integration into existing GIS workflows.

True Orthos: The generated True Orthos are now more complete, even in areas with low texture or insufficient overlap—such as tall tree canopies or complex structures—eliminating the need for manual gap filling. This results in more production-ready True Orthos straight out of processing.

3D Mesh: New in-app mesh editing tools enable you to create multipatches to correct anomalies in output meshes. These tools are especially effective for fixing gaps on reflective surfaces like glass or noisy results in shadowed areas. Edits trigger reprocessing only for affected tiles, making corrections fast and efficient.

Selective Tile Reprocessing: Beyond mesh editing, selective tile reprocessing enables you to regenerate only the portions of DSMs, True Orthos, or Meshes that need correction based on a shapefile. This dramatically reduces processing time and increases product generation efficiency.

Reflectance Data Support: Reality Mapping products can now be generated from reflectance satellite imagery data such as Maxar's ACOMP or Airbus Reflectance product. This expands the vendor specific products type natively supported for Reality Mapping processing.

GCP Manager: Ground Control Points (GCP) are central to producing accurate Reality Mapping outputs. This release delivers significant workflow improvements that streamline GCP management and boost precision.

Improved Auto-Correlation Accuracy

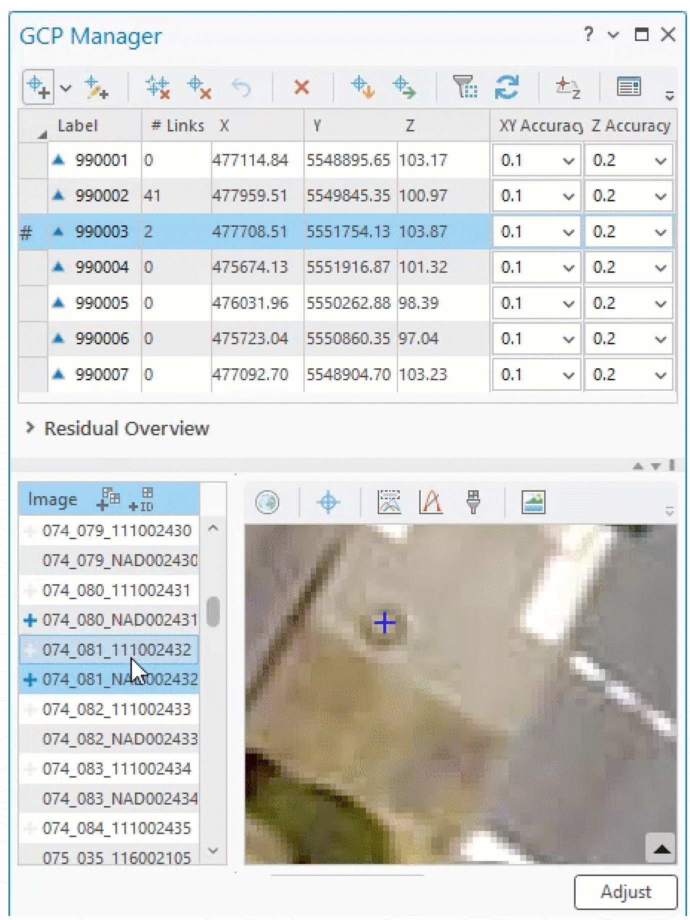
- Improved algorithms deliver more reliable GCP matches, reducing mis-correlations and improving overall alignment quality.

Manual GCP Tagging

- Users can now manually tag GCPs on multiple images before running auto-correlation. This reduces blunders, improves matching confidence, and improves alignment accuracy.

Quality-Based Sorting of Tagged GCPs

- After tagging, images can be sorted based on a calculated quality score—ascending or descending. This makes it easier to spot outliers, detect issues, and correct errors faster.



CEPT: Future-Proofing Planning Education with GIS & AI

CEPT University is strengthening future-ready education by embedding GIS, spatial analytics, and emerging AI applications into its academic and professional programs. By combining hands-on lab work, real-world projects, and interdisciplinary learning, the university ensures graduates are prepared to work with large-scale geospatial datasets and AI-driven decision systems. **Prof. Manushi Bhatt, Assistant Professor, Faculty of Technology, CEPT University, Gujarat,** shares how they are achieving this.

What core GIS and geospatial skills are considered essential for urban planning graduates today?

In the past few years, cities in India have gradually recognized the importance of GIS mapping and are increasingly turning to geospatial technologies for urban planning and management. Especially after the implementation of the Smart Cities Mission and AMRUT (Atal Mission for Rejuvenation and Urban Transformation) program, numerous cities have adopted GIS-based field surveys, data creation, and mapping. As practicing urban planners, fresh graduates are often required to know the basics of mapping and analysis using GIS tools. This includes the ability to create, clean, process, and manage spatial data. It is fundamental for planners to be able to interpret maps, aerial images, and satellite images.

Beyond the basics, the trend these days is to also process remote sensing data to extract urban growth patterns that can be utilized for urban growth prediction modelling, which in turn can be a key input for future land use zoning and master plan proposals. Site suitability analysis is another technique that helps planners in identifying potential sites for proposing parks, schools, hospitals, landfills, treatment plants, etc., by analysing various factors – again helpful for future master plan and other urban interventions. **Skills in thematic analysis of satellite data, including Land Surface Temperature (LST) Mapping, Urban Heat Island (UHI) Effect, and Blue-Green Infrastructure Mapping, can give planning graduates a valuable edge.**

In the present times, cities are progressively leveraging Artificial Intelligence (AI) and Machine Learning (ML), Internet of Things (IoT), and Big Data Analytics to build smarter urban solutions - skills that future urban planning graduates are likely to be expected to apply in their careers. Lastly, urban planning graduates should also have the ability to make interactive maps and dashboards to engage the public and effectively convey their proposals.

Over the years, have you observed a mindset change in students toward learning technologies like GIS? Why do you think these changes are occurring?

There has been a noticeable shift in the way students perceive GIS, and this is mainly driven by the change in professional practice. **Unlike earlier times, even the smallest of companies and startups in any sector look forward to hiring a graduate with a basic GIS skillset these days.** This has eventually given rise to the interest of students from various disciplines to learn GIS and apply it in their work. Especially in the urban sector, governments have started putting in the requirement of GIS-based mapping in many projects. This is a very strong motive due to which the students are interested in learning it. At the same time, even professionals are interested in gaining GIS Certification as it has become an essential skill.

There are prospective students who look forward to GIS beyond a mere tool to conduct their mapping tasks and intend to pursue a Master's degree in GIS and Remote Sensing. This is due to the growth in the geospatial industry with strong career opportunities, data-driven decision-making, interdisciplinary applications, and emerging technologies using UAVs, AI, ML, IoT, Big Data Analytics, etc. The geospatial industry is witnessing significant development, slowly becoming an integral part of planning, governance, and data-driven development.

At CEPT, what steps are taken to align GIS training with evolving career roles in urban planning and governance?

At the university, we have a studio-based learning pedagogy which is a combination of classroom-learning, peer-learning, hands-on learning, and industry engagement. Students identify real-world issues in the study areas, conduct analysis using various tools and techniques, including geospatial tools, and come up with final proposals to address the issues. Input from the industry is in the form of expert sessions conducted throughout the process by practitioners.

Studios themed 'GIS for smart cities' and 'Urban Digital Twins', alongside the other planning-oriented studios, offer an opportunity for the students to understand the applicability of GIS in urban planning and governance. Students closely observe the challenges in urban governance and try to address them using GIS-based solutions, including Apps and Dashboards. For 3D Modelling, different interfaces like City Engine, ArcGIS Pro 3D, and Revit are explored, post which 3D-based solutions for particular study areas are developed. The curriculum of the Master's programs at the university is designed and updated continuously to reflect emerging industry trends and professional practices, enabling students to graduate as industry-ready professionals.

How do you think the use of emerging technologies like AI, digital Twins, IoT, etc., is changing decision-making in urban planning and management? Is CEPT working towards developing relevant skills in its students? Please give a few examples.

The National Geospatial Policy enlists an important milestone – to develop digital twins of major cities in India. Many city authorities have already started working on it as well because **Urban Digital Twins are dynamic representations/ virtual replicas of the entire city, and they can be immensely helpful in planning and governance.** IoT sensors act as an important element in making these dynamic replicas, as they will fetch real-time data. AI and ML can help make sense of that data, like object detection, accident hotspot detection, predict faults in water pipelines, predict pollution levels based on past trends, etc. So, numerous scenarios can be tested with the entire framework, enabling better decision-making.

Since the geospatial industry is rapidly growing, new developments are emerging every day. CEPT focuses on keeping the students updated on these through expert input sessions, hands-on workshops, and more. Students pursuing the Master's in Geomatics course at the University learn Python, Google Earth Engine, Web GIS, and AI/ML, which help them in their academic projects.

The integration of artificial intelligence and geospatial technologies (GeoAI) has a lot to offer. The GeoAI tools offered on Esri's ArcGIS Living Atlas of the World were very helpful during our 'Geospatial Technologies: Predictive Modelling & Analysis' studio, conducted in the second semester of the Master's in Geomatics course in Spring 2025. A prediction of PM2.5 for Mumbai was achieved using Random Forest and LSTM models, trained on hourly data from 2021 to 2024. Another student forecasted Urban Heat Island (UHI) in winter and summer seasons for Pune by training monthly LST data using LSTM and Res-CNN models. Timeseries AI tool in the GeoAI toolbox in ArcGIS Pro was used in both these projects. In another studio on 3D Modelling, the deep learning package - Building Footprint Extraction available on Esri's ArcGIS Living Atlas of the World was very helpful to prepare the Level of Detail (LOD) 1 Model of multiple neighborhoods across Ahmedabad.

Thus, at CEPT, we are adopting new GeoAI tools that can minimize manual digitization by automating data extraction, enhancing the scalability of our workflows, and enabling predictive analysis without the need for extensive coding or scripting.

RESEARCH PAPER

Seismic Vulnerability Assessment of RC Building Stocks in Western Ahmedabad Using GIS-Integrated Capacity Spectrum-based Approach

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Abstract

Seismic risk in India's rapidly urbanizing corridors poses a significant threat to reinforced concrete (RC) building stocks in major cities like Ahmedabad and Surat. In this study, we integrate structural fragility analysis with ArcGIS-based spatial visualization to produce detailed, parcel-level vulnerability maps that can guide targeted disaster mitigation. Field-survey attributes—including building typology, age, occupancy, and height—were digitized and tagged in ArcGIS Pro, then combined with mean damage indices (DSm) derived from nonlinear static pushover analysis and Incremental Dynamic Analysis (IDA). Spatial statistics and cluster analysis were applied to identify high-risk hotspots across both urban centers. Results reveal that mid-rise RC frames in Ahmedabad's western zone exhibit mean damage indices up to 2.8 (moderate–severe), while similar buildings in Surat's western zone show indices around 2.4, indicating elevated collapse potential under Maximum Considered Earthquake scenarios. Comparative modeling of IS code 1893 older (2002) versus revised (2016) version indicates up to 16% greater overstrength and reduced fragility in modernized designs. The resulting GIS maps and vulnerability clusters provide municipal authorities, urban planners, and policymakers with actionable insights for prioritizing seismic retrofitting and land-use planning. By visualizing risk at the parcel level, this approach fosters data-driven resource allocation and strengthens community resilience against future seismic events.

1. Introduction

India is acknowledged as a highly seismically active region globally, with urban centres becoming increasingly susceptible due to unregulated construction, deteriorating infrastructure, and rapid population growth. Ahmedabad, classified within Seismic Zone-III according to IS 1893 (Part 1): 2016, sustained significant structural damage during the 2001 Bhuj earthquake, despite the epicentre being more than 250 km distant. The event revealed systemic shortcomings in structural design, construction quality, and seismic readiness within urban areas of Gujarat. Reinforced concrete (RC) buildings built before the implementation of contemporary ductile detailing provisions demonstrated significant failures attributed to soft-storey mechanisms and insufficient lateral resistance. The western zone of Ahmedabad, governed by the Ahmedabad Municipal Corporation (AMC) and the Ahmedabad Urban Development Authority (AUDA), has experienced considerable growth since the early 2000s. This area consists mainly of low- to mid-rise RC frame structures, many of which were built before the implementation of updated seismic regulations, including IS 1893:2002 and IS 13920:2016. The concentration of vulnerable building stock, along with rising population density and varied soil conditions, increases the seismic risk profile of the region. Observational studies reveal significant noncompliance with ductility and seismic detailing standards, even in constructions completed after 2002, which exacerbates the vulnerability of the built environment.

Seismic vulnerability assessment (SVA) is essential for urban risk mitigation, allowing planners, engineers, and policymakers to assess structural fragility under earthquake loading and pinpoint critical areas that need retrofitting or redevelopment (Gondaliya et al., 2025; Barbat et al., 2006). The Capacity Spectrum Method (CSM) is a robust and computationally efficient analytical tool for estimating structural performance under lateral seismic demand. The conversion of nonlinear pushover curves into spectral coordinates enables the identification of performance points, fragility thresholds, and anticipated damage states through CSM (Gondaliya et al., 2022; Barbat et al., 2010). The integration of Geographical Information Systems (GIS) has become essential for seismic risk modelling at the urban scale. Geographic Information Systems facilitate the spatial integration of structural attributes, soil classifications, and hazard data, thereby generating vulnerability maps and prioritizing interventions.

ArcGIS Pro functions as an effective platform for digitizing building footprints, organizing field-collected survey data, and visualizing fragility distributions within a specified region. This study combines CSM-based nonlinear analysis with ArcGIS spatial mapping to evaluate the seismic vulnerability of reinforced concrete building stocks in the western zone of Ahmedabad. The study employs detailed field surveys, representative structural modelling in SAP2000 (2023), and fragility function calibration to identify high-risk clusters and assess the effectiveness of updated seismic codes. The results are anticipated to assist AMC and AUDA in executing proactive retrofit strategies, distributing emergency response resources, and developing zoning-based seismic resilience plans.

2. STUDY AREA AND BUILDING STOCK CHARACTERIZATION

2.1) Geographic and Urban Context

IS 1893 (Part 1): 2016 places Ahmedabad, India's fastest-growing city, in Seismic Zone-III. The city has rapidly urbanized westward along S.G. Highway, Prahladnagar, and Bodakdev in the past two decades, building residential, commercial, and institutional projects. The AMC and AUDA-governed Western Zone has the most new building, economic activity, and infrastructural investment in the city. The western zone has flat topography and medium-stiff alluvial soils with moderate seismic amplification potential. AMC infrastructure borehole data indicate soil profiles with varied depth to hard strata, which may worsen site-specific seismic sensitivity. Figure (1) shows the Thaltej, Vastrapur, Satellite, Bodakdev, and Jodhpur are in the region between 22.99°N and 23.05°N and 72.49°E and 72.56°E.

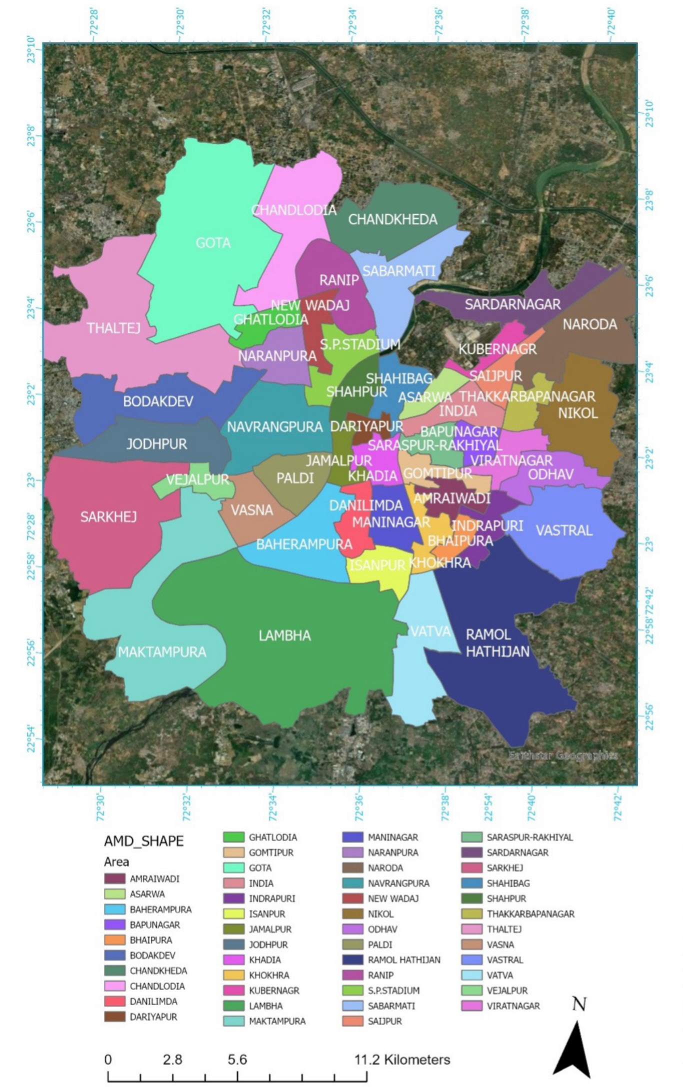

Figure 1: GIS-based Damage Index of the West Zone in the Ahmedabad City

2.2) Typology of Reinforced Concrete Structures

The built environment in the Western Zone predominantly comprises RC moment-resisting frame buildings with unreinforced masonry (URM) infill walls. These are supplemented by a smaller subset of RC frames with structural shear walls and a few institutional bare-frame RC buildings. Based on construction attributes, the structural typologies are categorized into three primary classes:

i. RC Frame with Masonry Infill (RC-MI) represents almost 85 – 90% of the building stock. These buildings often exhibit plan irregularities, non-ductile detailing, and soft-storey configurations, particularly in mixed-use typologies with commercial ground floors.

ii. RC Frame with Shear Wall (RC-SW) Found in newer high-rise developments and public facilities, these structures offer improved lateral resistance and exhibit higher ductility under seismic loading.

iii. Bare Frame RC Structures (RC-BF) is typically observed in parking or institutional blocks, these rely entirely on frame action for seismic resistance and are uncommon in residential sectors.

2.3) Building Classification by Age, Height, and Occupancy

A stratified classification scheme was adopted to characterize the RC building stock based on construction era, height, and functional occupancy:

i. Construction Era:

- **Pre-2000:** Largely non-engineered RC buildings lacking seismic detailing.
- **2000–2016:** Structures designed per IS 1893:2002, often without nonlinear analysis or accurate stiffness modelling.
- **Post-2016:** Buildings designed per IS 1893:2016 and IS 13920:2016 with improved ductile detailing and lateral strength.

ii. Height Category:

- **Low-rise:** 1–3 stories
- **Mid-rise:** 4–7 stories
- **High-rise:** ≥8 stories

iii. Occupancy Type:

- **Residential:** Dominant category, comprising over 75% of the surveyed stock.
- **Commercial/Mixed-use:** Includes retail complexes
- and buildings with ground-floor commercial occupancy.
- **Institutional:** Schools, hospitals, and government offices, primarily low to mid-rise.

2.4) GIS-Based Mapping and Inventory Compilation

A hybrid survey methodology combining field data collection and remote sensing was employed to prepare a geospatial inventory of RC buildings. Using ArcGIS Pro and Bing Maps, building footprints were digitized and tagged with essential structural and occupancy attributes, including: (i) Year of construction, (ii) Number of stories, (iii) Structural system (RC-MI, RC-SW, RC-BF), (iv) Functional occupancy (residential, commercial, institutional), (v) Visible damage indicators (e.g., cracks, settlement). Survey teams composed of trained engineering students collected data from 476 buildings across 27 AMC wards. This sample covered approximately 15% of the total Western Zone stock and included 284 residential, 132 mixed-use, and 60 institutional/commercial buildings. GIS-enabled visualization facilitated thematic classification, zoning-level damage mapping, and cluster detection of high-risk zones. Preliminary analysis highlighted Vastrapur, Chandkheda, and Nigam Nagar as neighbourhoods with high concentrations of pre-code mid-rise buildings lacking lateral load-resisting systems.

3. METHODOLOGY

3.1) Capacity Spectrum Method (CSM)

The Capacity Spectrum Method (CSM) provides a performance-based analytical framework for evaluating the seismic demand–capacity relationship of buildings. In this study, nonlinear static pushover analysis (NSPA) was performed for selected RC archetypes, followed by transformation of the force–displacement curve into Acceleration–Displacement Response Spectrum (ADRS) format, as per the ATC-40 guidelines.

The CSM identifies the performance-point as the intersection of the capacity curve (from NSPA) and the demand curve (from IS 1893:2016 elastic response spectra for Zone-III). This intersection indicates the maximum expected displacement and acceleration the structure will endure under Maximum Considered Earthquake (MCE) conditions. Spectral acceleration (Sa) and spectral displacement (Sd) were computed using the following transformation for each control node:

$$\alpha_1 = \frac{\left[\sum_{i=1}^{N}(W_i.\Phi^2{}_{ip})/g\right]^2}{\left[\sum_{i=1}^{N}(W_i)/g\right]\left[\sum_{i=1}^{N}(W_i.\Phi^2{}_{ip})/g\right]} \text{ and } \alpha_2 = \sum_{i=1}^{N} \frac{\sum_{i=1}^{N}(W_i.\Phi^2{}_{ip})/g}{\left[\sum_{i=1}^{N}(W_i.\Phi_{ip})/g\right]\varphi_{cp,p}}.$$

where, V = Base shear, W = Seismic weight, α_1,α_2 = Modal participation factors, Δcp = Roof displacement at control point. The bilinear idealization of the capacity curve was used to define yield and ultimate points, facilitating damage state classification.

3.2) Structural Modelling and Nonlinear Analysis

SAP2000 v23 (2023) was used to simulate Western Zone construction procedures in nine sample RC building models. These models were grouped by height (low, mid, high-rise) and design era (pre-2000, 2002–2016, post- 2016). Key modelling assumptions: The structural modelling for the specified RC frames used fck = 25 MPa concrete compressive strength and fy = 415 MPa steel yield strength. We applied a dead load of 2.0 kN/m² and a live load of 0.75 kN/m², following IS 875: Part I and II (1987) recommendations. Modelling a 150 mm slab as a rigid diaphragm ensured realistic in-plane floor stiffness and force distribution simulations. Fixed supports at the base of all columns ensured translation and rotation constraint for boundary conditions. According to IS 1893:2016 seismic zone categorization, the soil was medium-stiff. We used nonlinear hinge modelling to simulate seismic demand inelasticity. To model realistic frame performance under combined axial and lateral loads, beam members had M3 (flexural) hinges and column elements had P-M2-M3 (axial–biaxial flexural interaction) hinges. The hinge properties and acceptance criteria were developed according to ASCE 41-13 and FEMA 356, providing a rigorous foundation for nonlinear static pushover analysis and fragility estimate. First- mode triangular lateral load distribution was used for nonlinear static pushover. Each building model's base shear vs. roof displacement capacity curves were converted to ADRS format.

3.3) Fragility Function and Uncertainty Quantification

Fragility curves were constructed to express the conditional probability that a building will exceed a specific damage state (slight, moderate, severe, or complete) for a given spectral displacement demand. A lognormal cumulative distribution function was adopted:

$$p_k\,(S_d) = \mathrm{P}\,[\mathrm{DS} \geq DS_k \mid S_d] = \Phi\left[\frac{1}{\beta_k}\ln\left(\frac{Sd}{S_{d,ds}}\right)\right]$$

Where, S_d = Spectral displacement demand, $S_{d,ds}$ = Median displacement at damage state threshold, β_r = Logarithmic standard deviation (uncertainty factor), and Φ = Standard normal cumulative distribution function. The uncertainty factor (β) accounts for aleatory and epistemic sources of variability arising from material properties, geometric configuration, modelling assumptions, and ground motion characteristics.

As equation (3) demonstrated, a damage grade threshold is derived from the building structure's yield and ultimate spectral displacement.

$$S_{d,k} = \begin{cases} S_{d1} = 0.7D_y & \textit{slight damage state} \\ S_{d2} = D_y & \textit{moderate damage state} \\ S_{d3} = D_y + 0.25\,\mathrm{I}D_u - D_y\mathrm{K} & \textit{severe}\text{ damage state} \\ S_{d4} = D_u & \textit{complete damage state} \end{cases}$$

Where, D_y = yield spectral displacement, D_u = Ultimate spectral displacement.

To calibrate fragility functions, a binomial distribution was fitted to the empirical damage probability data, and a least-squares optimization was used to match the lognormal and binomial distributions. This approach also enabled the computation of the mean damage index (DS_m), which quantifies the expected severity of damage for each model.

3.4) Fragility Function and Uncertainty Quantification

A geospatially linked structural database was developed using ArcGIS Pro v3.0. Field survey data were digitized and tagged to building footprints using georeferenced base maps (AMC and Bing Maps). Each surveyed structure was characterized by attributes such as: Year of construction, Structural type (RC-MI, RC-SW, RC-BF), Occupancy type, Number of stories, Observed physical damage indicators. The collected data were integrated into thematic GIS layers representing: Building typology distribution, Damage state probability zones, Vulnerability cluster hotspots. Spatial cluster analysis and classification were performed to identify regions exhibiting high concentrations of seismically vulnerable structures. These maps serve as essential tools for urban planners and emergency response agencies.

4. RESULTS AND DISCUSSION

The outcomes of the seismic vulnerability assessment for RC buildings in the Western Zone of Ahmedabad were interpreted through four primary dimensions: structural capacity response obtained from nonlinear static pushover analysis, development of fragility curves including uncertainty quantification, spatial vulnerability distribution using GIS-based cluster mapping, and a comparative evaluation of design-era-based seismic performance. These components collectively provided a comprehensive, multi-scale understanding of regional seismic risk.

The nonlinear static pushover study of nine exemplary RC building archetypes by height (low-, mid-, and high- rise) and construction period (pre-2000, 2002–2016, and post-2016) produced detailed capacity spectra. The ADRS response curves showed unique lateral strength and deformation patterns. Low-rise buildings like LRC- Pre, LRC02, and LRC16 attained early yielding states with limited ductility, as shown in the Table [1] by their 18– 36 mm spectrum displacement capabilities and 1500–2000 kN base shear capacities. Mid-rise frames like MRC- Pre and MRC02 showed inelastic deformation with 350 mm ultimate displacements and 5500–6800 kN base shear capabilities. High-rise buildings with shear walls, such as HRCS16 built after 2016, had greater lateral stiffness, with maximum base shear near 9000 kN and spectral displacement capacity over 650 mm, indicating improved ductility and energy dissipation. Compared to IS 1893:2016 spectral demand for seismic Zone-III (PGA = 0.16g), older buildings attained their performance points at lower displacement levels, making them more susceptible to early-stage seismic damage.

Lognormal distribution functions were used to construct fragility curves for all archetypes, including damage thresholds based on spectral displacement criteria and calibrated uncertainty values (β). These curves helped predict building damage states: minor, moderate, severe, and complete. MRC-Pre and LRC-Pre, older structures, had strong fragility gradients with 50% chance of serious damage at 116 mm and 133 mm spectrum displacements. All archetypes had uncertainty factors from 0.43 to 0.93. Buildings built after 2016 (e.g., HRCS16) showed increased design consistency, smaller uncertainty bands (β) = 0.35–0.61), and lower fragility due to compliance with IS 1893:2016 and IS 13920:2016. The mean damage index (DSm) confirmed these findings. Pre- 2000 frames with DSm values above 2.5 were more likely to sustain severe to total damage under maximum calculated earthquake (MCE) scenarios. Post-2016 buildings have DSm values below 1.75, indicating greater seismic resistance.

Integrating fragility data, capacity spectra, and DSm values with spatially mapped Western Zone building inventory in ArcGIS Pro (2025) helped assess seismic risk distribution. The thematic layers identified many vulnerability clusters. High-risk sites including Chandkheda, Nigam Nagar, and Vastrapur had older mid-rise RC frames without shear walls and DSm values over 2.5. The majority of these structures

Table 1: Probability of occurrence of selected RC frame building for seismic hazard scenarios zone-III.

Model ID	Probability of Occurrence					DS_m
	No-damage	Slight	Moderate	Severe	Complete	
LRC-Pre	0.00	0.04	0.18	0.48	0.30	3.10
MRC-Pre	0.01	0.08	0.34	0.37	0.20	2.70
HRCS-Pre	0.15	0.34	0.38	0.10	0.03	2.05
LRC02	0.02	0.12	0.32	0.40	0.14	2.50
MRC02	0.03	0.16	0.36	0.34	0.11	2.35
HRCS02	0.20	0.40	0.30	0.08	0.02	1.85
LRC16	0.10	0.28	0.36	0.20	0.06	1.95
MRC16	0.15	0.33	0.34	0.15	0.03	1.75
HRCS16	0.36	0.44	0.17	0.03	0.00	1.25

were built before the 2002 seismic code modification. Satellite and Jodhpur had heterogeneous building portfolios, including pre- and post- 2002 constructions, indicating partial compliance and intermediate fragility. Post-2016 RC frames with shear walls and ductile details were found in low-risk zones like Prahladnagar and Thaltej, lowering vulnerability scores. This seismic risk distribution helps the AMC and AUDA prioritize retrofitting and enforce policy.

RC frames constructed under IS 1893:2002 performed better under earthquake loading than those modelled by IS 1893:2016. Post-2016 models like HRCS16 showed 30–40% improvements in base shear capacity and damage start delay due to material behaviour modelling and ductile details. Models with 20-25% lower uncertainty (β values) increased deterministic fragility forecasts. In particular, none of the post-2016 models exceeded FEMA P-695's 10% collapse probability threshold under MCE-level ground motion. Two out of three pre-2000 buildings exceeded this threshold, emphasizing the necessity to upgrade mid-rise RC frames built before contemporary seismic norms.

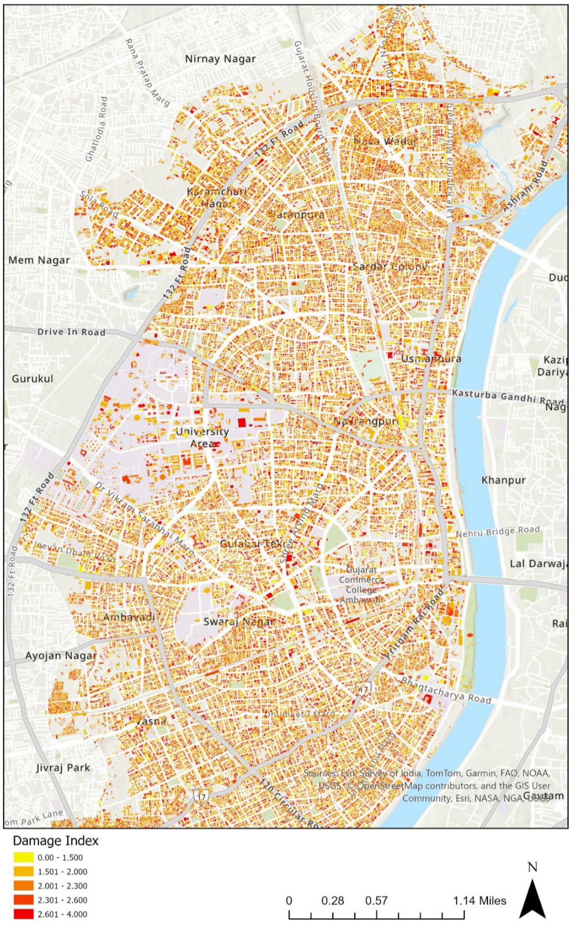

Figure 2: GIS-based Damage Index of the West Zone in the Ahmedabad City

Conclusion

This study presents an integrated framework for SVA of RC building stocks in Western Ahmedabad using nonlinear pushover analysis, CSM, and GIS-based spatial mapping. The findings emphasize the structural fragility of pre-code buildings and offer valuable insights for municipal risk mitigation strategies. Nonlinear analysis of sample RC building typologies showed that pre-2002 mid-rise RC moment-resisting frames have poorer lateral strength and ductility than post-2016 shear wall constructions. The fragility curves were derived from performance points and damage state thresholds identified by CSM. Former buildings, especially mid-rise frames with soft-storey layouts and poor seismic details, have high fragility and damage indices. GIS-enabled spatial mapping of building typologies, fragility characteristics, and damage indices identified Western Zone high-risk zones. Chandkheda, Nigam Nagar, and sections of Vastrapur were significant clusters of seismically sensitive buildings. Retrofit prioritizing, regulatory enforcement, and emergency readiness must begin in these regions.

The design code comparison showed IS 1893:2016 and IS 13920:2016's performance advantages. Post-2016 buildings had better lateral strength, lower spectrum displacement demands, and narrower fragility estimation uncertainty bounds. These findings support urban India's requirement for code-compliant design and enforcement. A scalable structural simulation, fragility modelling, and geospatial analytics tool is presented in this study. It helps local governments, urban planners, and emergency responders create seismic resilience in rapidly urbanizing Indian cities.

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How Utah—America's Most Urban State—Uses Data to Solve Housing Affordability

By Patricia Cummens

When governors face a crisis, they often ask the same question first: "Show me where we are." In 2024, housing affordability topped state policy agendas. Leaders turned to maps to understand current inventory and identify sites for new units.

Utah faces constraints that make every housing decision critical. With mountains hemming in development and the federal government owning 64 percent of the state's land, there's little room for sprawl. But constraints aren't unique to Utah—every state faces limitations, whether coastal boundaries, farmland preservation, water scarcity, or infrastructure gaps. When easy options disappear, states need strategic choices about where and how to grow.

Utah's geographic squeeze creates pressure for data-driven decisions. The state wants to welcome the next generation of homeowners. That requires knowing exactly what land is available and which infrastructure investments unlock the most opportunity.

Steve Waldrip, Utah's senior advisor for housing strategy, describes Utah's geography bluntly: "Everybody lives in a bobsled chute." About 80 percent of Utah's population lives packed into the narrow 150-mile corridor stretching south down Interstate 15 from the Idaho border.

"We're not a Phoenix or Las Vegas or a Dallas where you can just keep sprawling," said Dejan Eskic, a housing researcher at the University of Utah's Gardner Policy Institute. This geographic reality, combined with economic forces, has priced out an entire generation of potential homebuyers.

Utah is pioneering a data-driven approach to housing affordability by bringing together state planners, university researchers, and local governments to coordinate solutions across the mountainous state's constrained geography.

Key Takeaways

- Governor Cox set a goal to build 150,000 new housing units, including 35,000 starter homes by 2028, spurring state agencies to create America's most transparent housing dashboard.
- Research on developers' margins reveals how infrastructure gaps and development fees increase housing costs, prompting state efforts to streamline projects.
- State data coordinators gather and standardize data from every county to boost decision-making.

Mountains hem in development along Utah's Wasatch Front, where geographic constraints make data-driven decisions essential for housing growth. New mixed-use development in Lehi combines apartments and commercial space—making efficient use of limited land.



Governor Spencer Cox made housing affordability a signature issue, setting a goal to build 150,000 new housing units, including 35,000 starter homes, by 2028. To counteract these limitations, Utah is pioneering a comprehensive data-driven response that other states are watching. Geographic information system (GIS) technology supports this—from inventorying public lands to mapping infrastructure gaps to tracking permitting timelines—providing the location intelligence that connects policy decisions to real-world outcomes (see sidebar).

A Generation Left Behind

Governor Cox's ambitious goal requires a map and accurate measurements. The plan coordinates four key players: Laura Hanson, the state's long-range planning coordinator; Eskic, a university researcher tracking housing economics; Laura Ault, who directs the Utah Geospatial Resource Center; and Waldrip, coordinating policy across agencies. Together, they're building the data foundation needed to understand not just where Utah stands today, but who's being left behind.

The wealth gap tells the affordability story in stark terms. According to the Federal Reserve data that Eskic tracks, the average renter in Utah holds $11,000 in wealth while the average homeowner has $400,000. "A lot of that net worth is in the equity of the house," he said.

This divide reflects a broader generational trend. Anyone born after 1990 faces housing costs that have far outpaced wages, creating the first generation in decades with less wealth-building opportunity than their parents. Buying a first home has become financially out of reach for millions of young adults.

This gap creates the policy questions Eskic examines: What types of housing are being built? And what can people afford? Developers face a bind. They can't sell high-end homes because, Eskic notes, "the market's tapped out," but local regulations often prevent building affordable housing.

The development process alone adds massive costs. Eskic estimates that a quarter of a project's budget gets spent before construction begins. The entitlement process—getting raw land approved for development—takes 18–24 months in most Utah cities. "Ask any developer in any part of the country and they'll say they hate that process the most," Eskic said.

Utah is addressing this by making state-owned land available for development. The Utah Department of Transportation recently announced plans to sell a 2.7-acre vacant parcel in Salt Lake City for affordable housing development. The site, formerly a maintenance facility, will become condominiums targeted at moderate-income buyers. It's an early example of how Utah turns underutilized public property into housing solutions, part of a broader effort to evaluate state-owned parcels for potential development.

Looking for Opportunities in the Data

For years, housing policy relied on what Waldrip calls "windshield data gathering"—officials driving around making assumptions. "All of our housing discussions are based on who drove what road recently and looked out and said, 'We've got a lot of apartments there, that place is fine,'" he said.

The Utah Housing Strategic Plan Metrics dashboard changes that. Built by the Utah Geospatial Resource Center (UGRC) with Eskic's team at the Gardner Policy Institute, the web-based tool tracks everything from cost-burdened renters to new construction permits.

UGRC director Ault explains that the dashboard reveals both available data and gaps, reflecting the Governor's priorities. The dashboard doesn't hide its limitations—it clearly marks where data exists and where gaps remain. This transparency drives action to fill those gaps.

Hanson calls this revolutionary for long-range planning. "If we can get the data on the map in a common form, then we can argue about the solutions and not the facts," she said.

The dashboard updates quarterly, tracking progress toward the 150,000-unit goal. As of October, the state had permitted 36,783 units—of which 5,801 are new starter homes—behind pace with three years remaining to close the gap. Eskic says the metrics show some success: rents have dropped while incomes have risen, making housing "a little bit more affordable this year than two years ago."

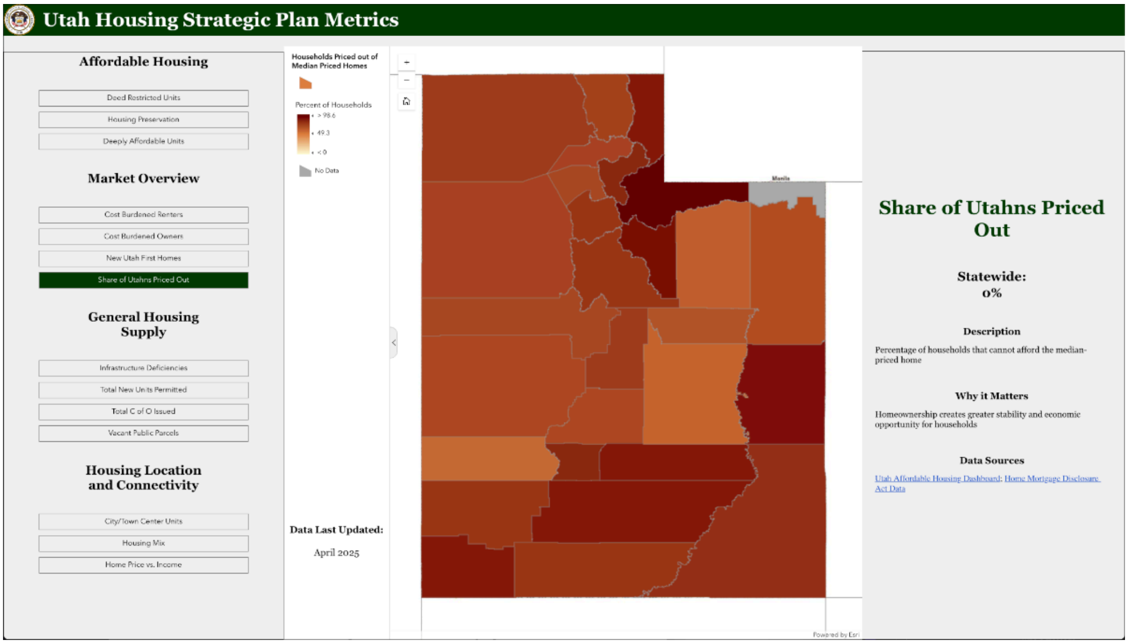
The tool tracks both market-rate and subsidized housing production and monitors naturally occurring affordable housing—older properties with lower rents. Each quarterly update brings more precision to understanding Utah's housing challenge and measuring progress.

This data-driven approach reveals something crucial: housing production isn't just about zoning changes or construction permits. The real bottleneck often lies in the infrastructure needed to support new development.

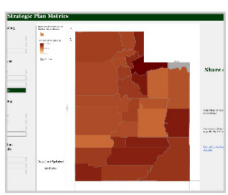
Exploring Utah's Housing Metrics Dashboard

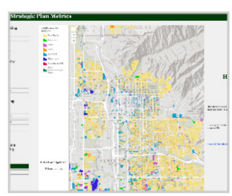
Utah's Housing Strategic Plan Metrics dashboard, built with GIS technology, offers multiple views that reveal different dimensions of the housing challenge:

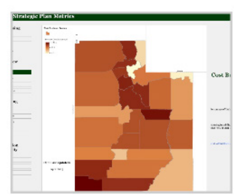
- Market Overview shows housing production trends and how supply matches demand across counties and municipalities.
- Cost Burdened Renters maps households spending more than 30 percent of income on rent—revealing where rental affordability creates the greatest pressure.
- Cost Burdened Owners tracks homeowners struggling with mortgage costs, highlighting areas where homeownership has become unsustainable.
- New Utah First Homes monitors progress toward the state's goal of adding starter homes, showing quarterly production numbers by location.
- Housing Supply displays entitled units, permits issued, and construction in progress—revealing where development is active and where it's stalled.
- Share Priced Out compares area median income to housing costs, showing which communities have lost affordability and by how much.



The "Share Priced Out" view compares area median income to housing costs across every Utah county—revealing in stark red tones where homeownership has moved beyond reach for most households.







The Infrastructure Foundation

Behind Utah's housing shortage lies the less visible challenge of infrastructure capacity. New homes need water lines, sewer systems, stormwater management, electrical service, and roads. GIS maps these systems—showing where capacity exists, where gaps create bottlenecks, and where investments unlock development.

Waldrip calls infrastructure "a huge hole in our understanding." The state has detailed road data but lacks comprehensive information about water, sewer, and power networks. Without knowing existing capacity, planning for growth is guesswork. Federal security restrictions prevent water agencies from sharing system maps, even with other state agencies. This creates information silos that hinder coordinated planning.

Hanson describes a common scenario: A city approves 800 new housing units, but the project stalls. The development needs a $70 million water treatment facility—a regional infrastructure investment that would serve multiple future projects. "What city has the money to think that far into the future for big regional needs?" Hanson asks. Without knowing where water lines end, which pipes need upgrading, and where treatment capacity runs out, housing can't be built.

Hanson's goal is a 30-year plan coordinating all infrastructure investments—transportation, utilities, and stormwater. GIS overlays infrastructure networks with development plans, showing which projects share needs and where regional solutions make sense. A new water main might also support road widening and enable transit-oriented development. State law already requires station area plans around high-capacity transit, identifying space for 74,000 housing units near rail and bus rapid transit, with eventual capacity for 100,000 units.

Utah is also mapping publicly owned parcels that could support housing—from closed schools to unused staging areas—reducing land costs.

Multi-family construction progresses in Utah—the type of higher-density housing that the state's dashboard tracks quarterly to measure progress toward the 150,000-unit goal by 2028.

Building Cooperation Through Data Sharing

Utah's housing response succeeds because multiple players cooperate around shared data. UGRC serves as the central hub, standardizing information from 29 counties so state planners, local officials, and developers work from the same foundation.

Ault leads this effort, collecting roads, parcels, and address points from local governments and standardizing them.

The challenge varies dramatically by location. Salt Lake County has strong GIS systems. Rural counties might have one employee handling city recorder duties plus multiple other jobs. UGRC bridges this capacity gap.

The state funds technical assistance positions in seven regional associations of governments. These specialists help small communities digitize data and build GIS capacity. "We don't want to be the ones with the sticks," Ault said. "We'd rather have a bag of carrots."

This approach reflects Utah's collaborative traditions. UGRC has built relationships with local governments since 1982, creating trust that enables data sharing.

Governor Cox's clear goal for more housing creates urgency and permission for agencies to work differently. After decades of conversations about better data coordination, Ault sees real momentum. "I feel like right now it actually might be happening," she said.

Transparency is already changing local practices. Cities are streamlining permitting processes. Hanson is piloting detailed tracking with willing cities to measure where delays occur, replacing anecdotes with hard data.

This collaborative approach—combining state coordination, local capacity-building, university research, and transparent data—enables productive problem-solving. “The nice thing about data is there’s no judgment,” Hanson said. “It just is what it is.” When everyone sees the same information, they can focus on opportunities rather than obstacles.

The urgency stems from welcoming back the next generation. Eskic’s research reveals a unique “boomerang effect”—about 25 percent of people moving to Utah were born there, a higher share than any other state. These returning residents seek the communities they remember, but rising costs threaten to price them out. Governor Cox frames the challenge: “What will happen if our kids and grandkids aren’t able to eventually own property and buy a home in this state? We cannot let that happen.”

By building transparent data systems, Utah creates the foundation for strategic decisions that preserve opportunity for those who want to build their lives here.

Patricia Cummens

Patricia Cummens is the Director of Government Strategy and Policy Solutions at Esri where she provides guidance on state and national government initiatives and emerging policy issues. Her skills bridge the gap between policy and technology, helping governments understand the value of geospatial data and GIS technology for efficient, smart government. Topics of focus include access to housing and high-speed internet, as well as resilience to extreme events, and streamlined permitting. She works with executives including governors’ offices, the White House, and US Congress. She has experience as GIS Director for the New Jersey Department of Environmental Protection after launching her career with State of Minnesota.

Seven Steps to Enhance Housing Opportunity

- **Map Your Current Housing Landscape:** Track housing types, ownership versus rentals, vacancy rates, and year built. Map demographic and income data alongside housing costs to identify who needs housing most and where gaps exist between supply and need.
- **Identify Development-Ready Land:** Inventory publicly owned parcels that could support housing—from closed schools to unused government staging areas. Score properties for development feasibility based on proximity to transit, services, and existing infrastructure.
- **Map Infrastructure Capacity and Gaps:** Overlay entitled development sites with water, sewer, and power infrastructure capacity. This reveals where infrastructure deficits limit growth and helps prioritize investments that unlock the most housing units.
- **Strengthen Zoning for Housing Diversity:** Test zoning changes before implementing them by running development scenarios in GIS. Model impacts of allowing accessory dwelling units, missing middle housing, and transit-oriented development on traffic, services, and quality of life.
- **Streamline Permitting with Location Intelligence:** Digitize permit processes and track applications in real time with dashboards showing timelines by stage. Automate reviews, flag high-risk locations, and identify bottlenecks that slow development.
- **Target Assistance Where It’s Needed Most:** Combine housing, demographic, and lifestyle data to pinpoint where assistance programs should focus. Map income, housing costs, and available resources together to connect residents with programs and identify service gaps.
- **Make Progress Transparent:** Share data publicly through dashboards that update regularly, showing both current progress and remaining data gaps. Public transparency builds trust and enables evidence-based conversations about solutions.

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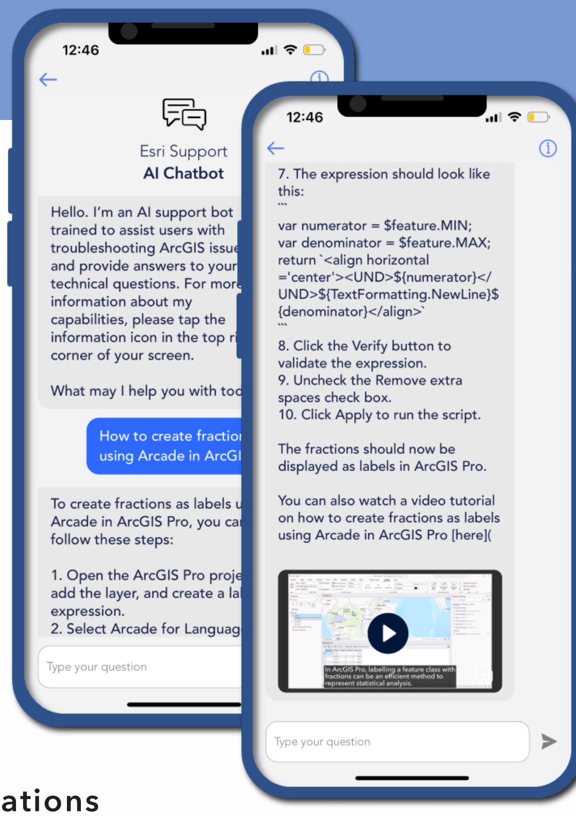

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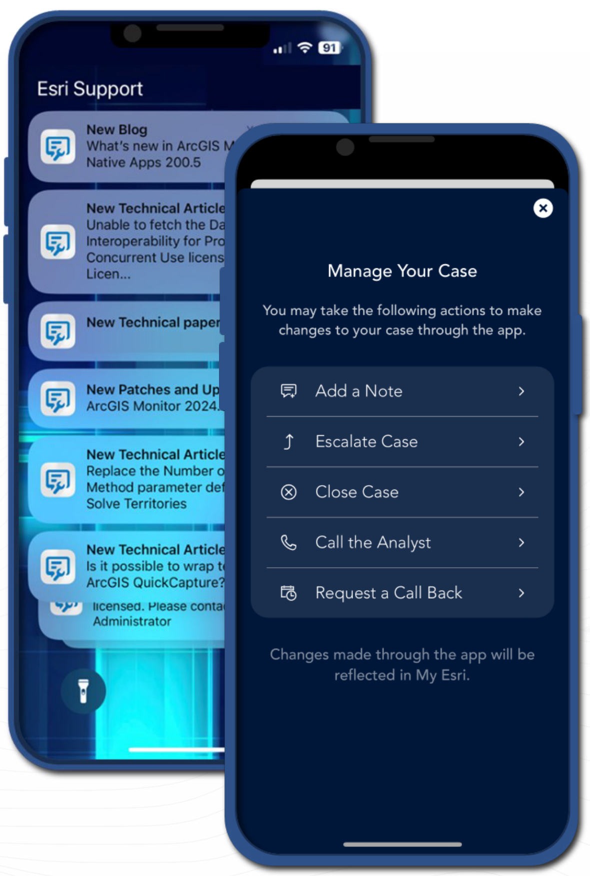

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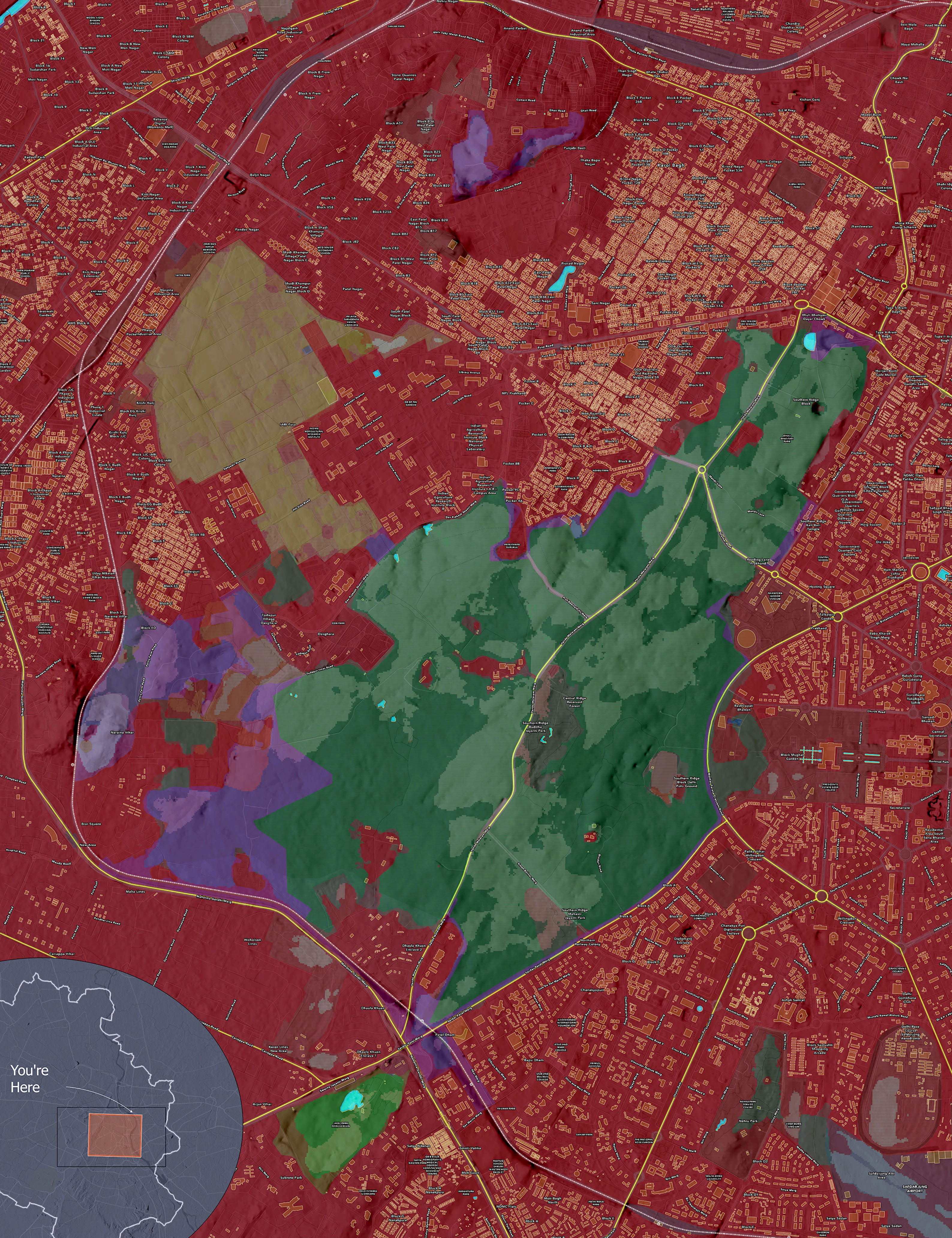
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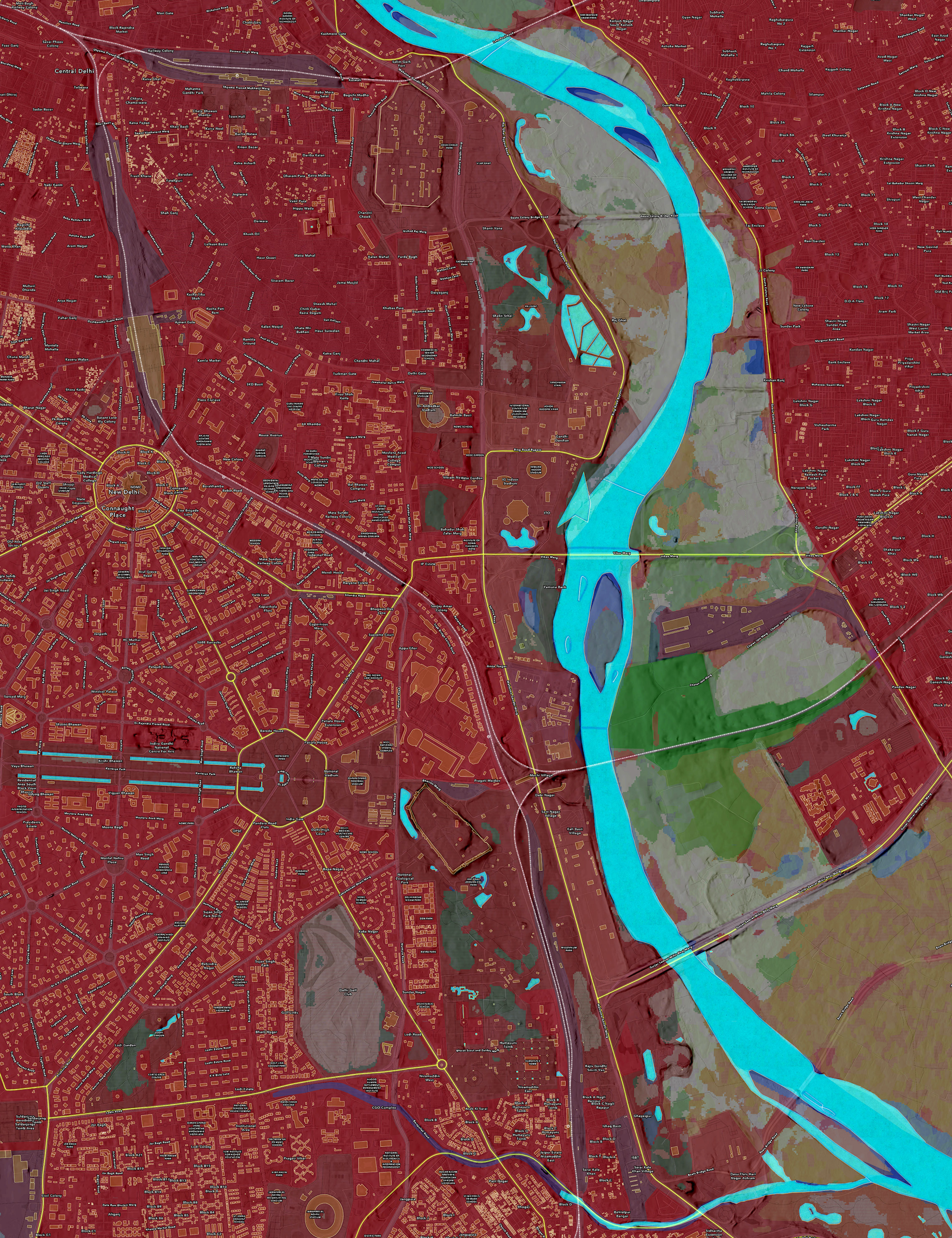

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