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GIS Analysis Methods and Technical Applications

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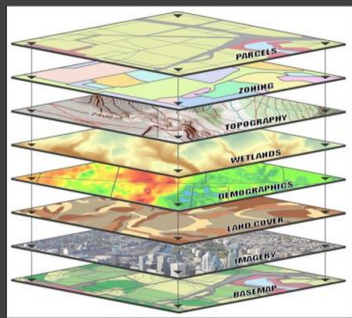

GIS Analysis Methods and Technical Applications

Credits: 6 PDH

Course Description

This course provide an overview of GIS analysis tools and methods, as well as various applications which may be performed more efficiently and effectively by GIS technology.

Topics

- The Principal Purposes of GIS; Analytical Methods using GIS
- Spatial and Proximity Analysis, Buffering, Clusters, Locate Nearest
- Overlaying Data Layers, Location and Viewshed Analysis
- Popular Processes and Toolsets used in GIS
- Route Optimization and Navigational; Accident Analysis
- GIS and ITS; Railway Systems Monitoring, Road Management
- GIS use for Capital Improvement Projects
- Nautical Routing: Waterway Navigation
- Ambulance, Hazmat, Wide Load Routing and Monitoring
- Bridge Maintenance Evaluations and Monitoring
- FEMA and FIRM Maps: Flood Risk Evaluation
- Disaster Risk Management, Mitigation, Eval., Planning, Response
- Insurance: Risk Management and Claims Adjustment
- Urban Planning and Development, Land Planning and Agricultural
- Gas Infrastructure, Geological, Petroleum, Mining
- Electrical Grid Planning and Monitoring, Advanced Metering
- Piping and Cabling Locating, Telecom and Cabling networks
- Water and Wastewater Infrastructure
- Supplier Distribution and Sales Route Management
- Logistics, Demographics, Sale, and Marketing
- The Process of Geocoding
- Properties, Facilities, and Space Management / Planning
- Zoning and Land Use Requirements, Mass Property Appraisals
- Parcel and Tax Jurisdiction Mapping Educational Applications
- Homeland and Border Security, Military and Law Enforcement
- Governmental Election Mapping, Jurisdictional Zones
- Crime Scene Investigations

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Chapter 1: GIS Analysis

GIS Analytics

GIS systems generally have two specific purposes: For creating thematic maps which represent a given theme, displaying a certain combination of data in order to visually describe a desired concept; for example a crime map which shows all of the car thefts in a particular area of a city, occurring between the years of 2001 to 2005.

Secondly, GIS systems allow for the analyzing of spatial and database data, and outputting of the results to a map composition, or textual files.

Thematic Mapping

There are a variety of specially-purposed maps which a GIS system can compose.

Some examples are:

- trucking company route maps
- inventory maps for property managers
- map police beat maps
- zoning maps
- electoral maps showing poll numbers
- epidemic maps showing cases of Lyme disease among a certain age group within a given boundary
- a map of the greater Chicago metropolitan area, showing all of the roads which begin with St.

If you can dream it, a GIS system can create it!

Once a GIS framework has been "built" with all of the desired data layers and attributtal data, maps of all shapes and sizes can be composed.

These maps can take features and elements from the assorted data layers, and combine them with the attributes from the database to compose hundreds of assorted maps for thousands of uses.

An Introduction to Spatial Analysis

What is Spatial Analysis?

This is the use of analytical and statistical processes, applied to spatially-located features and elements, in order to draw certain conclusions based on the geometric, geographical, and topological properties of the features.

Spatial analysis and the GIS environment can be applied to a variety of data and datasets, in order to visualize the relationships between groups of data.

Types of Spatial Analysis:

There are a number of methods used for spatial analyzing data:

Factor Analysis

This is a statistical method used to describe the variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors.

Those who deal with census report data and the results of surveys use this type of analysis. The large amount of data comes with a large number of variables which are usually inter-related to one another.

The use of Multivariate analysis or factor analysis reduces them to a smaller number of independent variables. It becomes easier to spot smaller processes this way by the third factor analysis; processes which would have remained hidden within the larger sets of data.

Spatial Autocorrelation

This method of analysis estimates the extent of dependency among observations in a spatial environment.

A spatial weight matrix is created and measured, showing the extent of the relationship between the observations for a given area (ex. - length of a common border or the distance between neighbors).

If the matrix returns:

- more positive values than predicted, this indicates similar arrangement across the geographical region
- more negative values, shows that the observations are dissimilar

Spatial Interpolation

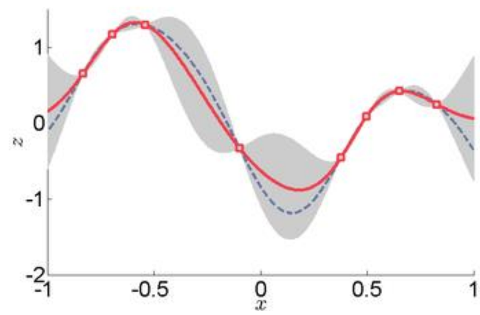
This analysis method is used to predict the variables at an unobserved location within an area, using the values obtained from observed locations.

Elevational data, precipitation, snow accumulation, water table heights, and population density are some of the types of data that can be computed using interpolation.

In GIS, interpolation uses vector points of known values, to estimate values at unknown locations.

Types of interpolation analysis:

- *Statistical Surface –* A statistical surface is any geographic entity containing a Z value for every X, Y location. Digital elevation models being the most common example; also: gradient, temperature, population, and economic potential.
- *Inverse distance weighted* - In this interpolation method, the sample points are weighted during interpolation, so that the influence of one point relative to another declines with the distance away from the unknown point you want to create.
- *TIN -* This is the method used in creating TIN data surfaces in 3D topographical models. A common TIN algorithm is the *Delaunay triangulation*. It attempts to create a surface by building triangles within nearest neighboring points.
- *Regularized Splines with Tension (RST)* – With RST interpolation analysis, bivariate and trivariate functions for interpolation from scattered data are derived. They are constructed by explicit minimization of a general smoothness functional, and they include a tension parameter that controls the character of the interpolation function.
- *Kriging* - is a method of interpolation (image) for which the interpolated values are modeled by a Gaussian process governed by prior covariances.



Example of Kriging in 1-D
Image Source: Wikipedia.org

- *Trend Surface interpolation -* is a method based on low-order polynomials of spatial coordinates for estimating a regular grid of points from scattered observations.

Spatial Regression

Spatial regression methods capture spatial dependency in regression analysis. Regression analysis is a statistical process for estimating the relationships among variables.

It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables.

This method of spatial analysis avoids the issues related to unreliable significance tests and unstable parameters, while providing information about the dependency of the involved variables.

Spatial Interaction Models

Gravity models

These are a type of analysis model which estimates the flow of people, material or information between different locations in geographic space.

Factors can include:

- *origin propulsive variables* - such as the number of commuters in residential areas; (propulsive, meaning capable of movement or flow toward another variable)
- *destination attractiveness variables* - such as the amount of office space in employment areas; (attractiveness, meaning capable of drawing other variables inward)
- *proximity relationships* - between the variables, measured in terms such as driving distance or travel time

For gravity models to be analyzed, the topological, connective relationship between regions of variables must be valid. For example, two spatially close neighborhoods may not display any significant interaction if they are separated by a highway.

After specifying the functional forms of these relationships, the analyst can estimate model parameters using observed flow data and standard estimation techniques such as "ordinary least squares" or "maximum likelihood".

Spatial-Temporal Models (Space and Time)

Spatial and Temporal Analysis

These types of analysis models arise when data is collected across time as well as space. An example would be that of a monitoring network of a river or stream's pollutant levels, or a network of meteorological stations, on which data is collected at regular time intervals.

Thus, this data analysis process has to take into account the spatial dependence between monitoring stations, as well as the fact that the observations at each monitor, typically are not independent but form a time series. In other words, one must take into account the temporal correlations as well as spatial correlations.

Other Analytical Processes used in GIS

Simple Mapping out of Data

"A picture is worth a thousand words" truly applies to a GIS map composition. One of the best means in which to relay information to others is to display it in a map.

The core function of a GIS system is to show a visual representation of complex data groups in a composite map.

This is possible, as the huge majority of data which is evaluated in various analyses will have a displayable, geospatial element to it. GIS provides the means for that data to be stored in a database and then represented visually in a mapped format.

Simply laying-out where things are in a clearly defined map is the first step in understanding spatial patterns and relationships.

For example, anyone who has read the legal description of a parcel's metes and bounds will understand, that by using written distances and angles to describe a property boundary is far harder to comprehend and visualize, than actually laying the parcel boundaries out in a site plan, with annotations.

A proper, visual presentation is everything, when attempting to describe complex concepts to others.

Proximity Analysis

A proximity analysis is a spatial analysis technique which is used to define the relationship between one location and another location within a specified "proximity".

The technique considers different factors such as social and economic demographics and the presence of competitor outlets.

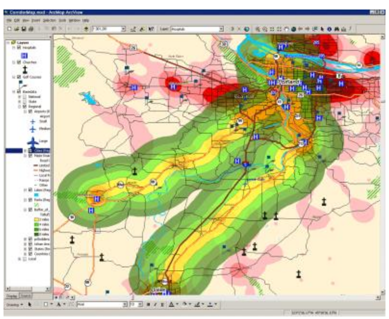
For an accurate proximity analysis, the various themes to be used must all use the same referencing (coordinate) system, otherwise results may be skewed.

Proximity analysis can be used to answer a variety of questions such as:

- How far is it from point A to point B when traveled through a linear network
- The simplest proximity analysis calculates distances between two given vector points
- What is the average distance from one point to another set of points or conditions
- What is the closest point in terms of time or cost taken to reach that point
- What is the "beeline" distance between one point and another within a layer
- How far to the edges of the nearest polygon

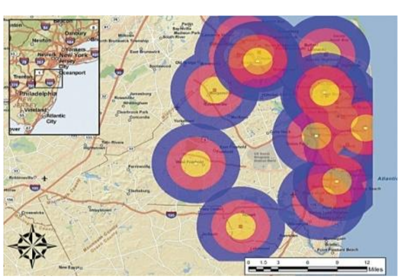
Buffering Analysis

This is a technique commonly used with proximity analysis to indicate the zone of influence of a given point.



Linear Buffering
Image Source: gisci.wordpress.com

Buffering involves creating a zone (see images) around a given point, line, or polygon (area) of a specified distance. Buffering is useful for creating a zone around a given geographic feature for further analysis using the overlay method.



Point Buffering
Image Source: ESRI.org

An example: a 3000' point buffer could be generated around a school to then use overlay analysis to find out how many students live within 3000' of that school, for establishing the percentage of students walking to school. Geocoding techniques could provide the home addresses of students.

This process could also provide a picture of distances traveled by the remaining students (for busing purposes, and school districting).

Polygon Buffering
Image Source: gis.stackexchange.com

Clustering Analysis

By applying various algorithms, it's possible to select a group of unrelated points on a theme map that match a given set of parameters.

A cluster could include constituents, where the distance between them is less than a specific amount, or include areas where there is a density of points greater than a specified level.

Typically a GIS will require varied degrees of iteration before applicable algorithms are found.

Typical forms of clustering models include:

- *Connectivity models* – depends upon simple distance-based relationships
- *Density models* –inclusion is determined by linking areas with specific densities of an event or population such as age groups in a given area

- *Subspace models* –elements are selected for inclusion into a cluster, by considering specific attributes of that element
- *Centroid models* – where elements in a cluster are determined by identifying the mean value of the cluster, which is most appropriate to the point being considered
- *Distribution models* – where elements are determined based on the application of a statistical distribution theory such as the normal probability
- *Group models* – those models where an algorithm cannot be established to create a shared link, thus requiring manual linking

Least Cost Path Analysis

This is a distance analysis tool within the GIS system that uses the least cost path method, which is a path between two locations (a source and destination point) in order to determine the most cost-effective route.

Cost can be a function of time, distance or other user defined criteria. When using least cost path analysis in GIS, the eight neighboring cells of a raster cell are evaluated, and the final path traverses the cells with the smallest accumulated cost value.

The process is repeated multiple times until the source and destination are connected. The completed path is the smallest sum of raster cell values between the two points which has the lowest cost.

Least cost path analysis is an important GIS concept to comprehend, as it has many applications; all of which can be of aid to users for saving time and money.

Overlay Analysis

This is a basic spatial analysis that allows a given area from one layer, to be overlaid onto data from another.

An example would be, finding the types of soils which underlay a proposed building site, or how many Italian restaurants are located within a neighborhood boundary.

There are two methods of performing this type of analysis:

- *Feature overlay* – a simple technique of dropping single or multiple points into a designated area
- *Raster overlay* – this technique is utilized when characteristics of multiple themes need to be examined because each area is referenced and combined on a grid basis

Location Analysis

The analysis technique is used to identify an optimal location for a particular use; such as finding a new business location based on queried criteria (density of specific customers, local specialty suppliers, near to distribution hubs, etc.).

This technique combines theoretical methods used to explain observed conditions, with an algorithm for identifying optimal locations, (based on maximal, minimal or median members of a given dataset).

Viewshed Analysis (Line of sight analysis)

This analysis technique uses the elevation value of each raster cell of a digital elevation model to determine visibility to or from a particular cell.

A viewshed is created from a DEM by using an algorithm that estimates the elevational differences from one cell (viewpoint cell) to the next (target cell), to establish a “line of sight” between points.

To determine the visibility of a target cell from the perspective of a viewpoint cell, each cell between the two points is examined for line of sight. Where cells of higher value are between the viewpoint and target cells the line of sight is blocked.

If the line of sight is blocked, then the target cell is determined to not be part of the viewshed. If it is not blocked, then it is included in the viewshed.

GIS Processing Tools

GIS Analyzing Tools

GIS software has many analysis tools built in to the software program (ArcGIS, for example). A great bit of analysis can be performed just using these built-in commands.

Below are just a few of the more commonly used commands:

Merge Tool

When there are hundreds of datasets which need to be combined into a single dataset, then the merge processing tool is used.

The merge GIS processing tool combines data sets that are the same data type (points, lines or polygons). When you run the merge tool, the resulting data will be merged into one.

Append Tool

The append tool is similar to the merge tool except, it adds data to an existing data set. Merging is taking two existing data sets, combining them together, to create a new merged data set.

Clip Tool

A clip is an overlay tool that cuts out an input layer within the extent of a defined feature boundary. This results in a new clipped output layer.

Dissolve Tool

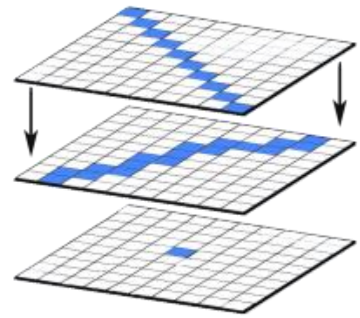
This processing tool unifies boundaries based on common attribute values. It merges neighboring boundaries based on common attribute values. An example of using the dissolve tool is to dissolve countries into continents.

In order to do this, you would need an attribute in each country record. For each country, there must be a continent field indicating the continent it's in.

Intersect Tool

The *Intersect* process is similar to the clipping process, as the output is defined by the extents of input features. The only exception being that attributes from all the data sets that overlap each other are preserved in the final data set.

This tool (Image) performs a geometric overlap, with all features that overlap in all layers becoming part of the output feature class with the attributes preserved.



Intersecting Layers
Image source: gisgeography.com

Union Tool

This tool spatially combines two data layers. It preserves features from both layers at the same extents. This tool tends to create a lot of features, after the layer combination process is run.

Erase Tool

This tool removes features that overlap the erase features. This GIS processing tool maintains portions of input features falling outside the erase features extent.

Other Tools

There are many more such tools used in GIS map composition and spatial analysis. This group is just a few of the more commonly used features of a GIS program.

Chapter 2: Uses for GIS in the Transportation Sector

GIS Uses in Transportation

Navigational: Route Optimization for GPS Navigation

Route optimization (Image) uses the GIS's linear network of topological data features: road arcs and nodes and related attribute data, to create travel routes based on user specified origins, waypoints, and destinations.

Based on the attributtal data for the various segments, the shortest route or fastest route is calculated to a given destination.

Closed roads, detours, construction zones, road hazards (accidents, downed trees, wash-outs), and other various road conditions can be taken into account, during the route optimization process, thus providing alternate routing options.

Google Maps, Yahoo Maps, and Bing Maps, all use route optimization algorithms for mapping out routes.

This same process can be used for nautical navigation when incorporating datasets with: channel marker data, shipping lane data, Bathyspheric (topography of the bed) and meteorological data, into the GIS system.

Companies such as UPS have used specialized delivery route optimization in their business model, saving millions of dollars in fuel and vehicle maintenance costs, while saving millions of minutes of idling and labor time.

Route with Waypoints

Image Source: yardsaletreasuremap.com

Navigational: Features Locating through Geocoding

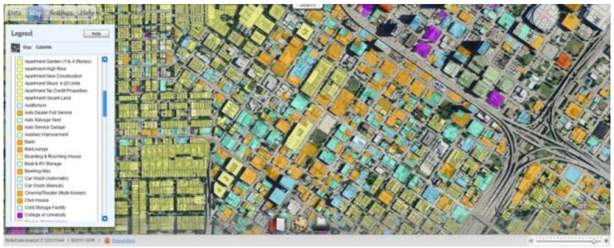
GIS features can be used in navigation for locating many landmarks such as residences, parks, restaurants and other businesses, government buildings, and more. These features are located through the process of geocoding.

Geocoding is the process of relating a description of a location, such as coordinates, an address, or name of a place, to a location on the earth's surface. Geocode descriptions can be entered one location at a time, or as a group of locations within a table.

The resulting locations are output as geographic features with attributes, which can be used for navigational mapping or spatial analysis.

You can quickly find various kinds of locations through geocoding, including:

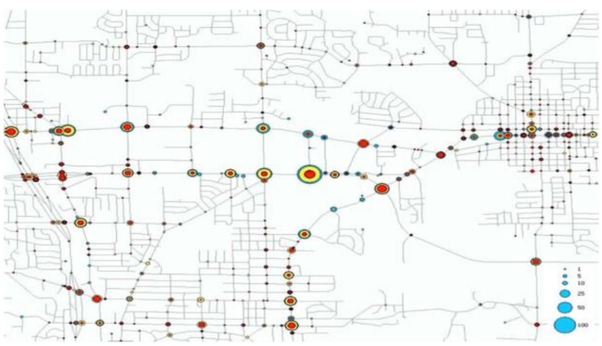
- Points of interest
- Geographical Features
- Bridges and Interchanges
- Stores and other businesses
- Parcel Features (see image)
- Restaurants
- Addresses
- Street intersections
- Zip codes



Parcel Features
Image Source: gdr.com

Transportation: Accident Analysis and Tracking
GIS is a valuable tool to use for analysis of traffic accident data (image). A number of traffic parameters can be used, such as: crash frequency (crashes per year), crashes per MEV (million entering vehicles), speed data, road geometry, traffic flow, plus many other types of traffic data.

Dangerous intersections (image), poor LOS (line of sight) areas, and other dangerous road locations with high frequencies of collisions which result in fatalities, injuries, or property damage can be mapped out, to form a better picture of signalization issues, vegetative LOS blockage, and other contributory factors.



GIS Buffering Analysis (used to tie traffic accidents to intersections)
Image Source: Penn State University

Transportation: Intelligent Transportation Systems
GIS is a key component of an ITS (Intelligent Transportation System). ITS systems, to some degree, have been implemented by nearly all of the 50 DOT's.

They utilize huge networks of digital cameras, traffic flow sensors, and other monitoring devices in order to provide real time feedback on traffic flow conditions. Traffic accidents, slowdowns, bottlenecking, and other traffic flow issues can be monitored in order to provide quick feedback for emergency response management, and other scenarios.

An ITS can provide a wealth of data feedback for uses such as weather monitoring, toll booth traffic, license plate recognition, facial recognition (still in a beta stage of development), interactive message board input, automatic ticketing of traffic offenders, and traffic density and flow.

Eventually, the topological data structure of GIS, integrated with ITS, may be the framework upon which the automated driving system is built (image).

Autonomous Driving System
Image Source: BMW

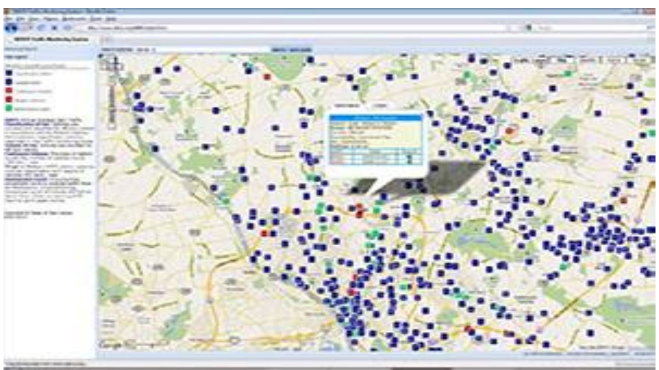
Transportation: Highway and Road Management
Managing modern roadway infrastructure has become a complex enterprise, from computerized signalization, and traffic incident management, to effective capital improvement planning, or pavement and maintenance activities; they all require a variety of complicated technologies to effectively manage the roads. GIS systems are an integral component of all of these management operations (image).

Roads are segmented into a topological data-structured, linear network of arcs (lines), and nodes (intersections, and dead-ends).

Each individual roadway segment (from node to node), is linked to attributes within the spatial database, which provide data on all of the parameters and characteristics of that particular road segment.

Attributtal data, such as:

- Inventory Definition
- Pavement Inspection
- Condition Assessment
- Condition Prediction
- Condition Analysis
- Work Planning
- Video logging
- Budgeting
- CIP status
- Etc.



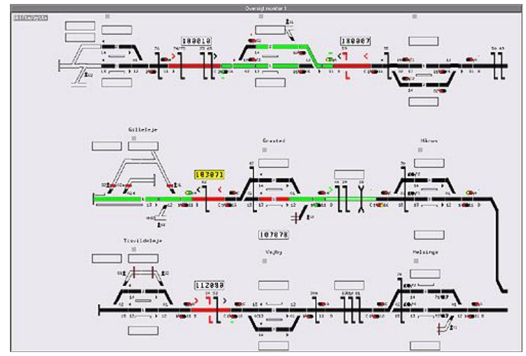
Roadway Management System
Image Source: FHWA

Transportation: Railway System Monitoring, Implementation, and Management

As with roadway management, GIS is also extremely useful in monitoring and managing railway and track conditions using linear network analysis methodologies.

Railway management (image) is a multi-billion dollar industry, with the potential to double in revenue, in the coming decade. The Rail Operation Management System (ROMS) market consists of the analysis of various types of railway management solutions such as:

- rail operations
- rail traffic
- rail assets
- rail control
- rail maintenance



Railway Traffic Management System
Image Source: btobrail.com

Transportation: Capital Improvement Projects

A capital improvement is any addition or alteration that adds to the value, prolongs the useful life, or becomes a permanent component of a “real” property.

In transportation, capital improvements are upgrades of the aforementioned types to roads, bridges, signage, and other constituents that improve the roadway infrastructure as a whole.

GIS is useful in assessing a road infrastructure for:

- Proposed Routes
- Hydrological Features
- Drainage Conditions
- Soil Bearing Capacity Potential
- Traffic Density Analyses
- Guardrail Requirements
- Conflict Situations

Uses in (CIP) Capital Improvement Projects

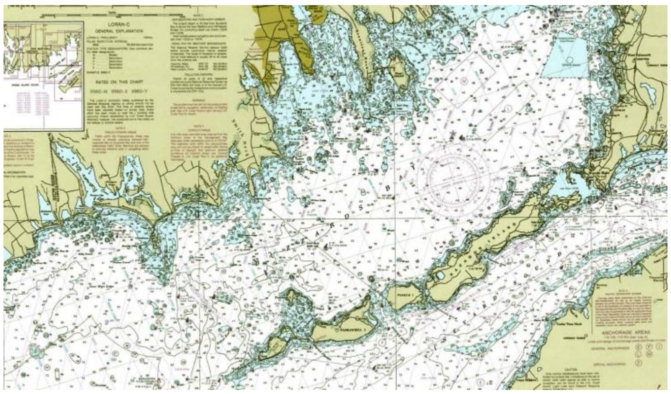
Nautical: Waterway Navigation

Navigable waterways can be mapped in GIS to provide a number of locational points for routing and feature identification:

- Channel centerlines
- Shipping lane centerlines
- Bathyspheric depth markers
- Seasonal water depths

- Obstructions in the water
- Diving sites
- Fishing locations
- No wake zones

As the map in the image below shows, a large amount of spatial data can be incorporated into a nautical map.



Nautical Map of Buzzards Bay
Image Source: buzzardsbay.org

Transportation: Ambulance Routing and Monitoring

When ambulances are dispatched to the site of an accident, every second counts both arriving at the scene and the trip to the hospital. When an ambulance is called during peak traffic periods, taking the wrong route could cost lives.

Ambulance Management Systems (AMS)

These are used in some areas to solve some of the problems encountered by emergency response vehicles in heavily congested cities.

An AMS is a combination of GIS, linear network analysis tools, and GPS, used for solving routing and accident location issues during normal and peak hours.

The typical AMS analyses are for scenarios such as:

- To identify the location of the accident scene on the road network
- To identify the ambulance's location on the road network in real-time using GPS coordinates
- To find the fastest route through which all the ambulances can reach the accident site
- To find the ambulance which can immediately reach the accident site as compared to other ambulances
- After finding the fastest route from the nearest ambulance to the accident location then the fastest route from the accident site to the nearest hospital is calculated
- If multiple accidents occur on the road network, find the fastest routes through which ambulances can travel to reach all the accidents
- To find the fastest routes from all the accidents to reach the hospital immediately
- During the peak hours of road congestion, analyze alternate routes and detours
- Identify intersections and road sections (image) which are problematic, and reroute during peak hours

Cars Pulling to Shoulder for Emergency Response Vehicle

Transportation: Bridge Maintenance Evaluations and Monitoring

Nearly one out of every nine bridges in the US is considered to be structurally deficient and potentially dangerous, according to the FHWA.

The cost to catch up with the nation's backlog of nearly 70,000 bridges in need of repair is an estimated $70 billion.

GIS is a valuable tool to use, in prioritizing those bridges in the most desperate need of refurbishment or replacement.

Roadway Inventory Systems

A vital part of a roadway inventory and maintenance system is the bridge attributtal data. A wide variety of bridge data can be incorporated into the geodatabase, concerning the bridge level of service and maintenance criteria.

For bridges that traverse bodies of water, hydrological data can be included such as stream-gauging data, water levels during peak runoff conditions, drainage criteria, and so forth.

Bridge scour report data can be included; as well as bridge inspection (image) scheduling and reports.

Bridge Inspections Team
Image Source: Oregon DOT

Transportation: Hazmat and Wide Load Routing

When specially-loaded vehicles need to travel from point A to point B, certain routing conditions are needed.

GIS route analysis can help to mitigate road issues for a number of given load scenarios, and identify problem road conditions and areas:

- Low power lines, bridges, and trees
- Congested Intersections
- Steep Inclines
- Narrow bridges and roads
- Jurisdictional issues
- Population areas
- Bridge and road loading limits

Chapter 3: Uses of GIS in Disaster Management

Overview

GIS can be used for a variety of uses in the evaluation, monitoring, management, and study of natural and manmade disaster incidents.

FEMA and FIRM Maps: Flood Risk Evaluation

The Federal Emergency Management Authority (FEMA) provides online access to the National Flood Hazard Layer.

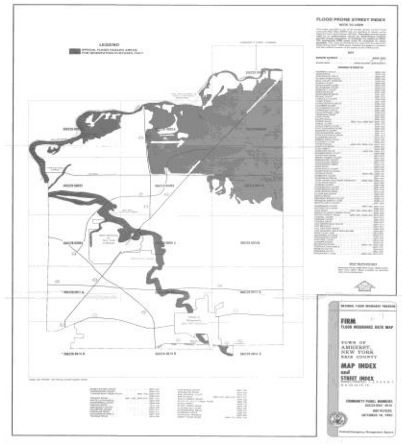
NFHL Database

The NFHL is a GIS database that contains FEMA's flood hazard map data (image) known as FIRM maps (or Flood Insurance Rate Map).

FIRM data is an excellent source of GIS overlay data for nearly any land use application to establish flood zones of multiple flood plains (ex. - 500 year flood plain).

The NFHL layers include:

- Flood hazard zones and labels
- River mile markers
- Cross-sections and coastal transects and their labels
- Letter of Map Revision (LOMR) boundaries and case numbers
- Flood Insurance Rate Map (FIRM) boundaries, labels and effective dates
- Coastal Barrier Resources System (CBRS) and Otherwise Protected Area (OPA) units
- Community boundaries and names
- Levees
- Hydraulic and flood control structures
- Profile and coastal transect baselines
- Limit of Moderate Wave Action (LiMWA)



Typical FIRM map
Image Source: FEMA

Fire Response Evaluations

GIS can be used to perform route analyses, to evaluate distances to fires from nearest firehouses, for evaluating the siting for proposed firehouses, or in determining how well the fire services cover a particular area (for insurance rating).

Fire Response Management System

A Fire Response Management System is similar in nature to the Ambulance Management System (AMS), which calls for getting the fire response vehicle from point A to point B in the shortest and safest time possible.

Risk Management and Mitigation

GIS systems can help with risk management and analysis by displaying which areas are prone to natural or man-made disasters.

Examples of Risk Assessment Analysis:

- *Environmental Risk Assessment (Manmade)* – For analyzing the potential for groundwater contamination from situations such as leaking underground fuel tanks; this type of spatial analysis involves a careful historical reconstruction utilizing data such as company records, census data, and historical land records, soil maps, and monitoring well data.
- *Flood Risk Assessment (Natural)* – This type of assessment could use FIRM map overlay data, with historical climatology data such as El Nino cyclical data, in order to analyze

the probability of a given storm occurring, along with flooding potentials for a given year.

Mudslide/Landslide Hazard Zone Evaluation

Landslide hazard zonation (LHZ) maps are used by land planners and engineers for selecting the most suitable locations, when assessing the development potential of a particular section of mountainous terrain.

LHZ maps are used for outlining appropriate mitigation measures in unstable, hazard-prone areas, as well.

GIS is used to assess soil conditions, terrain, watershed delineation, impervious and vegetative cover, slope characteristics and cyclical rainfall patterns of an area, in order to quantify soil liquefaction potentials (image).

Deadly mudslide in Washington State
Image Source: popularresistance.org

Disaster: Forest Fire Management

Maps are an essential tool in the fighting of wildfires.

GIS helps to analyze:

- where the fire is
- the rate at which it's spreading
- what the priority value targets are which require protection
- what are the risks to firefighters
- Proposed evacuation routes
- Where to build fire lines
- Where are the pockets of population located around the fire zone

GIS produces maps that answer these and provides the ability to quickly and efficiently analyze and disseminate data. Fire planning, preparedness, mitigation, incident response, and recovery are vital functions for managing effective wildland fire programs.

GIS helps wildfire agencies to:

- Access the real-time status of the fire and the state of the control efforts
- Develop fire management plans and mitigation strategies
- Optimize the placement and allocation of resources
- Enhance situational awareness
- Improve firefighter safety
- Develop budget requirements
- Support incident management mapping and analysis requirements

Wildfire Fighter in Action
Image Source: nytimes.com

Disaster: Planning and Response

Being prepared and organized is the first step to a successful emergency management and response plan.

A GIS system provides the ability to visualize critical infrastructure and vulnerable populations within a designated region, then access the availability of resources, and dispatch disaster response teams appropriately.

Past disasters such as Hurricane Katrina, have illustrated the need for proper preparedness plans, designed for an assortment of disaster scenarios within a variety of terrains and circumstances.

In Katrina, many lives were lost, along with billions of dollars' of property damage, due to poorly prepared, and coordinated response teams, and inadequate communication between various governmental agencies.

GIS helps to identify and prioritize the potential threats, and develop comprehensive evacuation, containment, and mitigation plans for the many specific ways a disaster can occur.

Preparedness Plans

With a well laid out preparedness plan created in GIS, response members from various agencies can enter a disaster situation with a common sense of the mission.

Emergency Preparedness

FEMA: Declared Disaster Recovery (DDR) Datasets

A major source of historical datasets for natural and manmade disasters is located on the FEMA website.

These datasets show the disaster areas which qualified for federally declared disaster recovery (DDR) funding, over the years. For example the year 2011 had 242 separate cases of qualifying declared disaster areas.

Typical data found on the FEMA site are:

- Geographical data
- News Stories
- Preliminary Damage Assessments
- FEMA datasets
- APIs (machine readable formats) to various data sources
- Financials

Insurance: Risk Management and Claims Adjustment

GIS is a great tool for assessing risk in the industry of insurance. Additional, the use of GIS in the field is a huge asset when adjusting claims.

GIS can be used in areas such as:

- managing the addresses of policyholders
- locating of risks
- logistics of claims handling
- Underwriting
- Reinsuring
- Corporate governance
- Sales and marketing
- Claims handling
- Customer service

Knowing where assets are located and their proximity to hazards is vital when developing insurance risk profiles.

Assessing Risk

In assessing automobile risks for insurance providers in a given area, GIS provides tools that allow users to combine an assortment of spatial datasets, such as vegetative densities, road conditions, accident clusters, and traffic flow patterns, to make more informed decisions as to the risks in insuring vehicles of a particular urban or rural region.

Following a major disaster such as a hurricane, tornado, or tropical storm incident, locating policyholders can be challenging when roadway markers or buildings are no longer in place.

Identifying claimants, organizing workloads, and setting claims adjuster routing are a few of the tasks that can be performed in GIS.

Through the use of GIS-enabled mobile devices, adjusters can efficiently locate customers and view relative datasets needed for settling claims.

Chapter 4: Uses of GIS in Earth Sciences

Uses in Earth Sciences

Geology: Soil Mapping and Geotechnical Evaluations

In various types of land development activities performed in a GIS setting, soil maps are an extremely useful data layer to use as an overlay. They can provide a clear picture of the land parcel's potential usefulness.

Though in depth soil testing is needed to establish the bearing capacity, drainage, or agricultural potential of the in-situ soil, soil maps can give a preliminary idea of what is to be expected.

Soil maps are produced to outline the results of a soil survey inventory. They provide a geographical representation reflecting the predicted boundaries of a region's soil types and soil properties such as the soil pH, soil textures, degree of organic matter, and strata depths.

Soil maps (image) are most commonly used for evaluating land, land planning, agricultural purposes, environmental protection and similar needs.

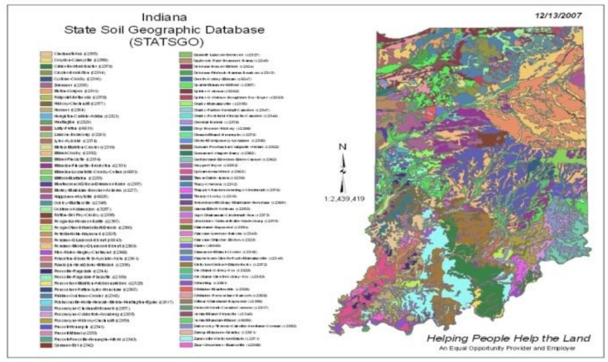
Standard soil maps usually show only the general estimated distribution of soils, accompanied by the soil survey report, though many newer soil maps are derived using digital soil mapping techniques performed on satellite imagery.

These maps typically show a higher level of spatial detail than on traditional soil maps. Soil maps produced using geo-statistical techniques also include an estimate of the model's potential level of inaccuracy.

Types of soil maps:

- hand-drawn soil polygon maps representing distribution of soil types
- simulated or predicted 2D/3D soil property maps (primary or secondary soil properties)
- simulated or predicted (2D) soil-class maps

For locating soil map data, the Natural Resources Conservation Administration (NRCS) division of the USDA has a wealth of soil survey data available to the general public.



Indiana Soil Map
Image Source: NRCS.USDA.gov

Geological Applications

Analyses of the earth sciences were at the forefront of the geospatial revolution. Geospatial analysis, using GIS, was originally developed to analyze problems in the environmental and life sciences, in particular ecology, geology and epidemiology.

It has since extended to almost every science and industrial application including defense, intelligence, utilities, natural resources, social sciences, medicine, emergency management, criminology, disaster risk reduction and management (DRRM), and climate change adaptation (CCA), to name a few.

Geologists use GIS in a variety of applications, such as to study geologic features, analyze soil types and conditions, evaluate strata, assess fault and seismic data, and analyze rock information characteristics.

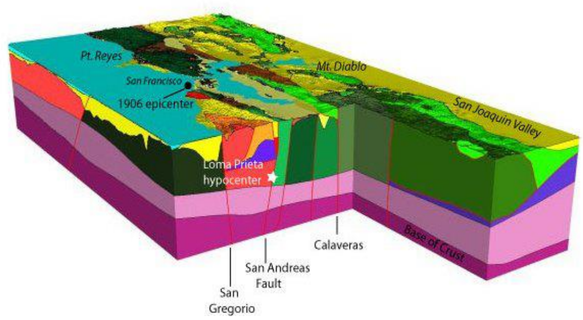
Oil Exploration

GIS technology provides the framework for oil and natural gas exploration. Petroleum resources data can be displayed spatially to improve visualization and analysis.

Geology: Seismic and Fault Activity Monitoring

Seismic and fault conditions (image) can be evaluated and monitored through the use of GIS systems.

Multiple datasets such as: geological surveys, sedimentary, strata, and soil maps, structural rock formation maps, structural planar features, and many other subterranean datasets can be used for seismic and fault analysis.



3D Geological Model of the San Andreas Fault
Image Source: earthquake.usgs.gov

Geology: Volcanic Activity Monitoring

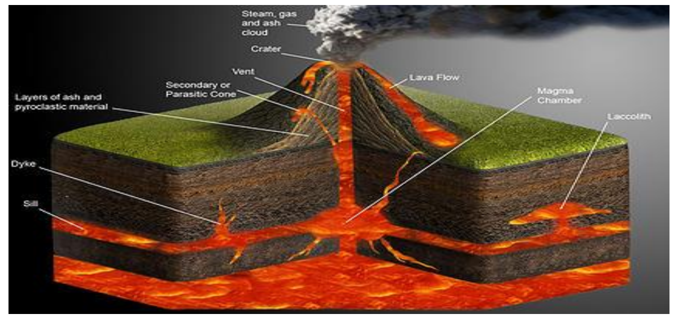
A volcanic eruption (image) has the potential to threaten a population living in range of a volcano blast with its accompanying lave flow; causing a variety of health issues even in areas thousands of miles away through airborne dispersion of gas and ash.

The superheated lava from the eruption of a volcano will incinerate anything in its path, while hot gases and ash can suffocate and burn. Volcanic ash (meaning the cooled ash), may form a cloud, and settle thickly in nearby locations, and when mixed with water forms a concrete-like material.

Volcanic hazard to human life and environment includes hot avalanches, hot-particle gas clouds, and flooding.

An impact assessment study of volcanic hazards can be created in the GIS by incorporating historical records of past volcanic activities; thereby potential volcanic hazard zones of varying degrees can be delineated.

Based on meteorological datasets, GIS allows the user to predict the potential ash plume directions of travel, create long distance fallout zones, and provide sufficient forewarning to those down wind.



3D Volcanic Diagram
Image Source: 3dgeography.co.uk

Oceanography: Marine Biology

Marine biology is the study of organisms within the oceans, seas, and other brackish bodies of water throughout the earth. In biology, many phyla, families and genera have species which exist both in the sea and on land; therefore marine biology classifies a species based on the environment in which that species is found, rather than on the taxonomy of the species.

Marine biology differs from marine ecology as marine ecology is focused on how organisms interact with one another and the environment, while marine biology is strictly the study of the organisms alone.

GIS has become integrated with every part of the aquatic sciences and limnology (the study of inland waters). GIS provides aquatic scientists with the methods to enhance all aspects of scientific investigation, from satellite tracking of wildlife migration patterns to computer mapping of habitats.

Governmental agencies such as NOAA, USGS, USDA, and US Fish and Wildlife Service utilize GIS to aid in their conservation efforts.

GIS is being used in a variety of aquatic sciences; fields like: limnology, hydrology, aquatic botany, stream ecology, oceanography and marine biology.

Applications include the use of satellite imagery to identify, monitor and mitigate habitat loss, water contamination, hypoxia dead zones, and species reductions.

Imagery can also show the condition of inaccessible areas. GIS can be used to track invasive species such as the lionfish, or endangered species (image) such as the Vaquitas, Bluefin tuna, whales, or sea turtles.

One of the advantages of the GIS system is the accessibility of openly shared, routinely updated web-based datasets.

Vaquitas – A Highly Endangered Species of Porpoise
Image Source: Alejandro Robles

Oceanography: Aquaculture and Mariculture Management

Aquaculture, or aqua-farming, is the farming of aquatic organisms such as fish, crustaceans, mollusks and aquatic plants such as seaweed and blue-green algae. Aquaculture is the cultivating and harvesting of freshwater and saltwater populations under controlled conditions, (while commercial fishing, is the harvesting of wild fish).

Mariculture is a specialized branch of aquaculture, which involves cultivating in the open ocean, an enclosed section of the ocean, or in tanks, ponds, raceways filled with seawater.

GIS can be used to monitor and map the aquaculture facilities and surrounding environment; to keep track of fish counts, contaminant runoff and migration, and track the nutrient, antibiotic, and mortality levels of the species populations.

Abalone Farming Enterprise
Image Source: Wikipedia.org

Oceanography: Glacial Morphology and Movement

Glacier morphology (change in glacial shape), is influenced by temperature, precipitation, topography, and other contributing factors.

Glaciers range from massive ice sheets, such as the Greenland ice sheet or those in Antarctica, to small round glaciers perched on a mountain.

Glacial types can be grouped into two main categories, based on whether ice flow is constrained by the underlying bedrock topography.

Ice sheets and ice caps (image) cover vast areas and are not constrained by the ground surface beneath them.

Vatnajökull ice cap in Iceland
Image Source: BMW

The main distinction between the two is area, with ice caps covering areas less than 30,000 square miles, while ice sheets span larger areas.

GIS is an effective way to monitor and evaluate glacial movements and seasonal changes in shape and size. Imagery from satellites such as MODIS, can capture various areas of the cryosphere on a daily basis, given a very tight window of time, in which to monitor the subtle changes in glacial morphology.

With its low spatial resolution and high temporal resolution, MODIS data is useful for tracking the changes in our earth's landscape over time.

Oceanography: Coastal Geology and Geomorphological Evaluations

Geomorphology deals with the ever changing coastal lines which surround the large bodies of water throughout the world. Most important is the shoreline changes (image) in our oceans and estuaries following major storm events such as hurricanes and tropical storms.

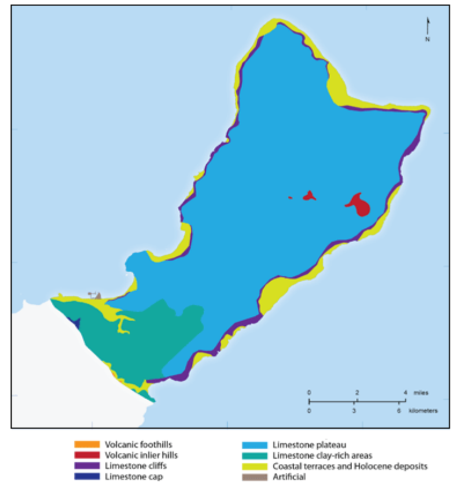
Coastal change is a potential risk which requires constant re-evaluations. Strong storms generate surges, waves, and currents which alter the sand deposits at coastal shorelines.

The USGS performs a range of studies that document, assess and model these coastal changes.

The USGS is tasked with assessing:

- the risks and vulnerabilities
- historical shoreline changes
- the geological structure and history of coastal regions
- sediment supply and transport
- sea-level rises
- the effects of storms on rates and impacts of coastal change

Using datasets such as these, GIS is able to model a number of scenarios, which are of use to coastal area management authorities, insurance companies, coastal planners, coastal homeowners, etc.



GIS theme map of Coastal Changes in Northern Guam

Image source: north.hydroguam.net

Oceanography: Coastal Line Vegetative Mapping and Conservation

In coastal regions, mangrove vegetation (image) is one of the best defenses against erosion, along southern estuaries and brackish waterways.

Mangroves offer nursery habitats for various marine species such as fish and crustaceans, helping to maintain the balance of the estuary ecosystems. Mangroves serve as rookeries, or nesting areas, for the coastal birds, while providing cover for various mammal species.

They also aid in the filtration of these brackish waters through abiotic and biotic retention, removal, and cycling of nutrients, various pollutants, and particulate matter from land-based sources, acting as a filtration barrier before they reach seagrass habitats.

The root systems slow water flow, facilitating the deposition of sedimentary matter.

GIS is a useful tool in evaluating and maintaining mangrove populations along brackish coastlines.

Through remote sensing, it is possible to visualize subtle changes in the increases or decreases of mangrove forests, thus being able to remediate the vegetative losses before erosion occurs.

Mangroves at the Water's Edge
Image Source: Wikipedia.org

Oceanography: Coastal Development and Management

Coastal development is a booming business in the 21st century, with nearly half of the American population living at or near the beach. With these densely packed populations comes a need for serious land and resource management.

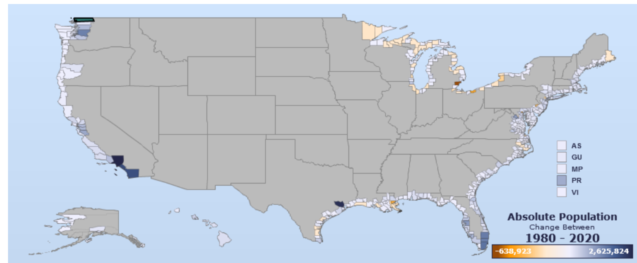
If these regions are not properly managed, much of the allure of coastal living could vanish, due to water pollution (ex. - nitrogen and phosphorus loading of the estuaries due to lawn fertilization runoff, sewage spillage, etc.), overfishing, traffic congestion, etc.

In previous years, waste water treatment was handled in many coastal areas by dilution purification (pumping the raw sewage offshore, and trusting the mixing of sewage with huge amounts of water to neutralize the wastewater).

In recent times, with the large populations now living at the beach, better solutions are required. With GIS, many new solutions to effective wastewater treatment can be explored.

Coastal land planning is similar to any other form of land development. However, the sensitive nature of the coastal ecosystem requires careful considerations to developing land with the need for environmental protective measures.

GIS helps in bringing together all of the complex nuances of ecological needs balanced with the needs of the tourism industry, a stable economy, and sustainable development.



Coastal Populations
Image Source: NOAA.gov

Snow Hydrology: Snow Cover and Thaw Runoff Evaluations

In the northern states of the US, the analysis of snow hydrology bears a significant degree of importance.

Snow runoff is used to supplement the water supply in many regions of the Northern states of the US, and Canada. However, an excessive snow season can cause big trouble with flooding, erosion, sediment loading in waterways, snow clearing and removal issues, etc.

Snow thaw has an influence on all of the surrounding ecosystems and their individual components. Too much or too little snowmelt runoff can drastically affect a region.

The negative effects of flooding and water variations due to runoff are not always preventable, but they can be predicted with the help of GIS and remote sensing technology.

GIS can be used to:

- estimate snow depths
- visualize the snowpack composition
- monitor snow cover and compare to historical observations
- improve flood protection
- predict the impact that sediments and pollutants in the snow runoff will have on receiving waterways

- understand and prepare for snow related disasters, such as avalanches

Hydrology: Water Reservoir Monitoring and Future Site Selection

The Armed Forces Corp of Engineers (USCOE) has built a number of dams throughout the US over the past century. These dam construction projects have created countless jobs, created water supply for municipalities, stabilized flooding, and created hydroelectric power for electrical companies and co-ops.

GIS systems could be utilized to model various aspects of water supply reservoir networks such as changes in water levels, using bathyspheric data combined with satellite imagery, climatology data, and water usage data.

In construction of new dams and reservoirs, GIS could be instrumental in the design process, by combining DEM data, soil maps, geological maps, etc.

Hydrology: Stream Gauge Monitoring and mapping

The USGS is the governmental agency tasked with monitoring of stream gauges throughout our nation's rivers and streams.

Stream gauging (image) is a technique used to measure the discharge, or the volume of water flow through a channel per unit time, of a stream. The water height in the stream channel (stage or gage height), can be used to determine the discharge rate of a stream.

USGS Stream gauging datasets are of great use when modeling scenarios such as flood management, sedimentary transport patterns, water reservoir management, or seasonal snow and storm runoff rates.

Gauging Station in England
Image Source: Wikipedia.org

Hydrology: Stormwater Management and Contamination Tracking

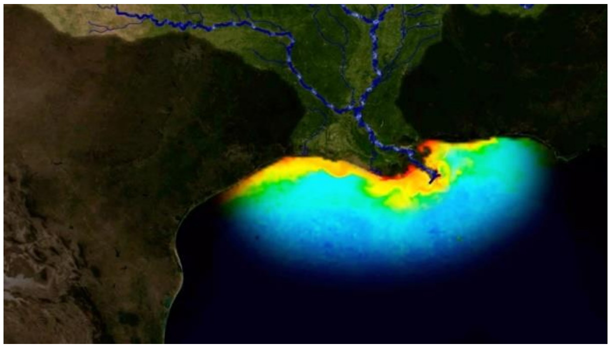
GIS is a great tool to use for visualizing hydrological processes which occur in a given region of land. By using elevational topological data and soil mapping for instance, various stormwater and hydrology situations can be modeled.

With a bird's eye view of a parcel of land along with adjacent land topography and existing soil conditions, watersheds can be delineated, runoff and infiltration rates calculated, while climatology and flood map data can be used to establish design storm parameters.

Much of the stormwater runoff winds up in the local lakes, rivers and streams, which will eventually make their way to the oceans (image) creating enormous ecological dead zones (hypoxic zones) void of dissolved oxygen, most plant life and marine species.

Various contaminants such as nitrogen, phosphorus, hydrocarbon fuels and solvents, and pesticides wreak havoc on the delicate ecosystems existing in our waterways.

GIS can be used for tracking the flow of contaminants in order to locate the sources of contamination and monitor levels of various pollutants based on monitoring stations.



Dead Zone in the Gulf of Mexico, from the Mississippi River Delta
Image Source: oceantodaynoaagov

Climatology: Global Warming Patterns

One of the most popular uses for GIS is climatology mapping; the spatio-temporal modeling of global climate changes and global warming or cooling trends.

GIS can map the global weather pattern changes over time, based on a wide variety of datasets and earth conditions.

To obtain relative datasets, a variety of climate data and weather data resources are available from the U.S. Dept. of Commerce's National Oceanic and Atmospheric Administration (NOAA). Key sources within NOAA include the NCEI, and the National Weather Service.

NOAA's NCEI

The most complete and comprehensive source for climate data is probably the National Center for Environmental Information (NCEI), which was formerly known as National Climatic Data Center (NCDC).

NCEI is responsible for the preservation, monitoring, and assessment of the national archives of climate and historical weather data and information. NOAA maintains separate Climate and Weather resource pages with links to data and information.

They charge for custom requests, but there is also much of the data which is free of charge when being accessed from an education web domain (.edu).

Climate data is tricky to use as there is such a variety based on and different stations record different elements and report at different intervals.

Also weather stations move over time, which can be problematic for local level analyses. It is best to verify the location coordinates of weather stations before performing local-level analyses by checking them in Google Earth using address information or other clues.

National Centers for Environmental Information
Image Source: NOAA.gov

Another useful source is the PRISM dataset from the USDA division, the Natural Resources Conservation Service (NRCS).

Global Drought Monitoring and Temporal Variations

Desertification is the elimination of topsoil layers due to climate variations such as El Nino patterns, or human activities such as deforestation.

GIS can have a profound effect in promoting acknowledgment and possible reduction of desertification.

In areas such as the western states, drought reduction, and proper water management practices have become a critical step in the future sustainability of the agricultural and economic welfare of states such as California.

With location based GIS analysis, it's possible to analyze which areas are suitable for planting new vegetation and where new irrigation systems can best be utilized.

An excellent source for drought-related datasets and GIS climate analysis tools is climate.gov, a divisional website of the NOAA site.

They have a wealth of GIS analysis tools and data groups for uses such as:

- *Greenhouse Gas Concentrations Graphing Tool -* based on data gathered from over 200 monitoring stations worldwide; it is called the Interactive Atmospheric Data Visualization (IADV) Tool
- *Extreme Weather Data Tables* (provided in commonly used tabular formats: CSV, XML, TXT or JSON)
- *Monthly Climate Conditions Interactive Map -* This is an interactive mapping interface which displays monthly obtained data for each of the 344 climate divisions in the U.S. Climate Divisional Database. View maps of monthly or yearly values, ranks, or anomalies for temperature, precipitation, heating and cooling degree days, and drought indices.
- *Severe Storms and Extreme Events - Data Table (Storm Events Database)* - Severe events have the potential to damage life and property. National Weather Service observers keep a comprehensive record describing 48 different types of severe events, from localized thunderstorms, tornadoes, and flash floods to regional events such as hurricanes, derechos, and winter storms.

Wildlife Management and Invasive Species Control

Habitat loss, pollution, invasive species introduction (such as pythons and anacondas in the everglades), and climate change, are all threats to the health and biodiversity of wildlife species.

GIS technology is an effective tool for managing, analyzing, and visualizing wildlife data to target areas where governmental management and intervention is required, and to monitor their effectiveness.

Recent competitions have been held in Florida, to see how many of the invasive snake species (pythons and anacondas) can be been captured or eliminated, offering prize money for those with the biggest snake or the most snakes.

GIS could be used by the event promoters, to gather coordinate data from all of the participating contestants, showing where the snake was caught, along with questionnaires which gather other useful data.

This data could provide a picture of the types of invasive species, sizes, and quantities, in order to gather a bigger picture of the clusters of snakes, and their predatory habits, etc. in order to begin the process of controlling their numbers to an acceptable level.

Similar low cost GIS based operations could be organized for destructive species such as lionfish, or the Eurasian feral pig (image).

Invasive Eurasian Wild Pig
Image Source: Wikipedia.org

Biological: Epidemiology

For epidemiological applications, GIS has the potential of linking disease exposure and confounding factors by location.

(Confounding factors cause or prevent the outcome of a study, distorting the measure of the effect of exposure or risk, because of its association with extraneous factors which influence the outcome of the study).

Examples of confounding data which can be incorporated through GIS:

- Data on outbreaks may be linked with census data providing a means for correlating outbreak incidents with age

factors of the affected population. Often data regarding confounders would be difficult and expensive to collect, but may be available through the census. A GIS serves as a tool to efficiently bring together many pieces of information relevant in monitoring for trends in incidence.
- Monitored exposure rates may be linked with meteorological data to model the dispersal of possible environmental contributory factors.
- Analysis of historical data based on previous outbreaks.

The ability of GIS to quickly link existing data on possible confounding factors suggests that GIS can be a useful tool for preventing environmentally related disease, and potential disease outbreaks.

Ecology: Biodiversity Patterns

Biodiversity is the number and variety of plants, animals and other organisms that exist. It is a vital component of a balanced ecosystem and ensures the survival of human species by providing food, fuel, shelter, medicines and other resources to mankind. The richness of biodiversity is dependent upon climate conditions and regional conditions.

All species of plants are known as flora and about 70,000 species of plants have been documented. Species of animals are known as fauna which includes birds, mammals, fish, reptiles, insects, crustaceans, mollusks.

Rapid environmental changes typically cause mass extinctions, with more than 99 percent of all species that have ever lived on Earth, estimated to have become extinct.

Estimates on the numbers of the Earth's present species ranges from 10 million to 14 million, of which about 1.2 million have been documented, while over 86 percent yet to be described.

GIS allows biologists the means to map out what species are found where, and in what predicted quantities. It allows them to analysis the interactions between the various plant and animal types, seeing which species are eradicating others; for example the lionfish, which is an invasive, well protected, voracious eater which is a highly predatory fish.

This fish has, in a very short time in history proceeded to eradicate everything in sight, systematically wiping other marine life off the planet.

Similarly the pythons and anaconda snakes which were set lose during hurricane Andrew are upsetting the balance of life in the everglades, eradicating much of the mammal life there.

GIS gives Fish and Wildlife management authorities the tools to effectively combat these invasive predators.

Burmese Python with a Florida Deer
Image Source: snakesinthisworld.blogspot.com

Ecology: National Wetlands Inventory (NWI) Datasets

The US Fish and Wildlife Service (FWS) established the National Wetlands Inventory (NWI) with the intent of creating a nationwide inventory of US wetlands, to aid in wetlands conservation efforts, and to provide biologists and others, data on the distribution and types of wetlands.

The NWI developed a wetland classification (image) system that is now the official FWS wetland classification system and the Federal standard for wetland classification, also developing techniques for mapping and recording the inventory findings.

Image analysts identify, classify and then map the wetlands and deep-water habitats from remote sensed imagery.

Wetlands Ecosystem
Image Source: en.wikipedia.org

As computerized mapping and geospatial technology has evolved, NWI began to distribute data via online "mapping tools" where information can be viewed and downloaded. Today, FWS provides its GIS data via an on-line data service called the "Wetlands Mapper".

The techniques used by NWI have recently been adopted by the Federal Geographic Data Committee as the federal wetland mapping standard.

This standard applies to all federal grants involving wetland mapping to insure the data can be added to the Wetlands Layer of the National Spatial Data Infrastructure. NWI also produces national wetlands status and trends reports used by the US Congress.

Ecology: Natural Resource Conservation: Monitoring and Management

GIS is a good tool for the monitoring and management of natural resource conservation efforts in the US.

Land

Crop, forest, pasture, and range lands comprise the majority of the land uses in the US, and the land uses receiving the majority of the conservation efforts.

Major land use natural resource concerns include:

- *Soil Resources* - protecting topsoil resources from erosion by wind and water
- *Soil Nutrients* - maintaining and enhancing soil quality
- *Water Resources* – protecting the quality of our water from contaminants, and the quantity from drought and wasteful practices
- *Agricultural and Forestry Resources* – maintaining sustainability, diversity, and growing conditions
- *Animal and Wildlife Resources* **-** preserving habitats, maintaining biodiversity, and preventing endangerment

The USDA is an excellent source for environmental, soil, hydrography, air, wildlife, and land use datasets. The Geospatial Data Gateway (GDG) found at the USDA's Natural Resources Conservation Service (NCRS) website provides access to a map library of over 100 high resolution vector and raster layers in the Geospatial Data Warehouse. It is a valuable source for environmental and natural resources datasets.

It allows for choosing an area of interest, browsing and selecting data, customizing the format, then downloading.

This service is made available through a close partnership between the three Service Center Agencies; Natural Resources Conservation Service (NRCS), Farm Service Agency (FSA) and Rural Development (RD).

Ethology: Studying Animal Behavior in the Wild using Biologgers and GIS

Ethology is the scientific and objective study of the ways in which animals behave in a natural, uncontrolled environment, under instinctive conditions. (When studying animals in controlled environments such as a lab, it would be called behaviorism).

Ethologists are particularly concerned with the evolution of behavior and the understanding of behavior in terms of the theory of natural selection.

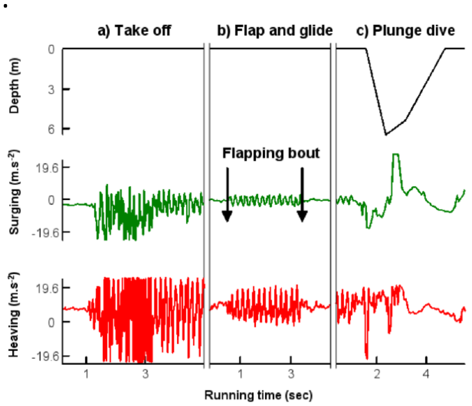
GIS is used in ethology to spatially envision the complex series of interactions which occur in nature between similar and dissimilar animal species.

GPS linked tracking devices, outfitted with accelerometers can provide digital data which, when combined with other datasets (from various other species, climatic data, drought conditions and weather data, topological data, etc.), certain patterns begin to emerge which explain animal behavior in ways, not otherwise observable.

The observation of the ways in which animals behave has long been restricted to captive subjects or at least to species that could be observed continuously in the wild.

In modern times however, monitoring of the behavior of free-ranging animals is possible through the use of miniaturized accelerometers, which combined with GPS recorders, can give us precise feedback on the spatial and temporal activities of animals in remotely located ecosystems.

The image below shows data retrieved from an accelerometer attached to the tails of free-ranging sea birds. The data feedback from these biologging devices helped in determining the following animal behaviors: Take off, landing/plunging and flight session.



Biologging Feedback from Sea Birds

Image Source: Ropert-Coudert

From this data, it was determined that within each flight session of the sea birds, an oscillating flapping pattern was present simultaneously in both wings, with each propulsive stroke recorded on the heaving axis resulting in a forward acceleration recorded on the surging axis.

When the flight session lacked these oscillating patterns, gliding then occurred. Also, preening on the water surface and walking on land were also identifiable from the biologger data graphs.

Environmental Impact Assessments (EIA): Studies and Analysis

GIS is a valuable tool to use, in the Environmental Impact Assessment (EIA) process, when it is properly implemented.

Along with identifying and analyzing potential environmental impacts, GIS is a powerful environmental planning tool.

GIS is often used for identifying and establishing environmentally sensitive sites which are suitable for uses such as waste disposal facilities. Overlaying various spatial datasets (soil type, vegetation, ground and surface water, geology etc.), with specific assessment criteria for each, can produce a map indicating suitable and unsuitable locations.

The accessibility to high quality, pertinent spatial data has improved significantly over the years, and data is becoming more accurate than ever before. Inferior quality spatial data still exists, however, and it is essential that the GIS user is aware of the quality of the spatial data prior to use.

The use of GIS in EIAs will continue to evolve as dealing with global warming becomes a worldwide priority.

In the future, standards and practices for spatial planning will become far more stringent and demanding, to meet the requirements of governmental and private sector authorities.

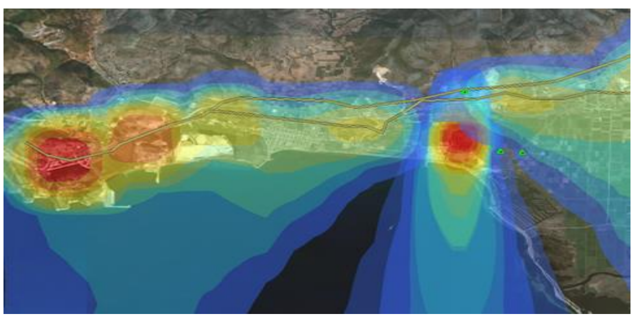
Environmental: Air Quality Pollutant Tracking

GIS is a handy tool to use for the monitoring and tracking of pollutant transport through the atmosphere.

The EPA provides different types of air quality data through numerous systems. These data can be separated into two standards, primary and secondary.

Air quality data includes the amount of pollution and other substances present in the atmosphere. This data (image) is measured by emissions monitors scattered throughout the nation.

Emissions data includes the amount of pollutants and other substances being emitted from facilities, vehicles, and other activities that release pollution into the atmosphere.



Air Pollutant Tracking
Image Source: intechopen.com

Archaeology: Mapping of sites

Proper and accurate site surveying and documentation are vital to historical preservation and archaeological digs.

The use of GIS in archaeological research and fieldwork provides efficiency and precision to the process of uncovering relics from the past.

By using GIS capabilities, relevant information that could impact archaeological sites and studies is careful and systematically recorded in a spatial environment. It is a valuable tool which contributes to the planning of the dig and management of the cultural resources.

There are a variety of processes and GIS functionalities that are used in archaeological research. Spatial analysis or distributional analysis of the information on the site helps in understanding the formation, the process of change over centuries of abandonment and decay, and in documenting the in situ conditions of the site prior to being disturbed.

In archaeology, GIS provides the ability to map and record data spatially, and to model and predict the locations of potential archaeological sites, by overlaying various spectrums of satellite imagery which can reveal subtle variations in the topological and subterranean layout which may be indications of underlying structures.

Angkor Wat Ruins

Using detailed radar interferometry images of the ancient city of Angkor Wat (image) in Cambodia, researchers were able to find previously undiscovered remnants of ancient structures and unnoticed hydrological features which will help to change the way that archaeologist view the lifestyles and progression of the ancient Khmer civilization.

These maps not only brought into question, the traditional concepts of the urban evolution of Angkor, but revealed evidence of temples and an earlier civilization either absent or incorrectly interpreted, on modern topographic maps and in early 20th century archaeological reports.

Lost City of Angkor Wat, Cambodia
Image Source: NASA

Linguistic Anthropology: Mapping Linguistic Patterns

Linguistic anthropology is the study of how language influences social behavior. It is a branch of anthropology that began with a project to document endangered languages, and has evolved to including most aspects of language structure and use.

It seeks to explain how language shapes communication, forms social bonds and identities and affects the dynamics of group participation, organizes cultural beliefs, and establishes theological doctrines.

GIS is useful in mapping and quantifying linguistic patterns, in order to visualize the what, where, and how of verbal communication.

Regional dialects can be diverse throughout a country, with some language variations only being spoken by small groups such as isolated villages with limited external influences.

GIS helps to delineated these pockets of language variations, and document and visualize patterns of contributing influences.

- *Ecology:* Biodiversity Patterns, National Wetlands Inventory Datasets, Natural Resources Conservation, Monitoring and Management
- *Ethology:* Studying Animal Behavior in the Wild using Biologging
- *Environmental:* Air Quality Control, Pollutant Tracking, Environmental Impact Assessments (EIA): Studies and Analysis
- *Geological Industries:* Oil Exploration, and Mining Industry Assets Management
- *Archaeology:* Mapping of Sites
- *Linguistic Anthropology:* Mapping Linguistic Patterns

Chapter 5: Land Planning and Agricultural Uses for GIS

Land Development

Land Development: Urban Planning and Development

GIS technology can be of use in analyzing urban growth potentials and establishing proper directions to expand (urban sprawl).

In order to identify the regions which are suitable for urban growth, certain factors have to be taken into consideration.

These factors include:

- Available land
- Terrain and topographical conditions such as watersheds, soil conditions etc.
- Areas which are conducive to utility expansion or have existing utility infrastructure in place: powerlines, water mains, treatment plants, etc.
- Existing nearby municipalities for annexation
- Traffic infrastructure (existing and potential for expansion)

GIS is an excellent tool for visualizing all of these factors and for spotting potential conflict situations which could cost millions to tax payers.

Planned Neighborhood
Image Source: sciencedaily.com

Land Planning: Land Acquisitions

In land acquisitions, GIS is a useful tool for accessing and evaluating potential parcels.

Datasets can be overlaid to investigate the following characteristics of property:

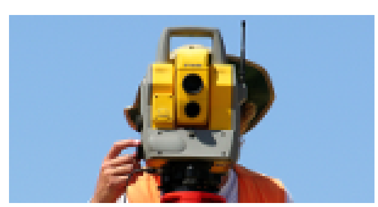
- Topological maps for watershed and drainage conditions
- Cadastral data for land history, taxation, and other parcel data
- Aerial Imagery for evaluating forestry potential, utilities availability, neighboring detrimental facilities and enterprises
- Soil maps to discover unsuitable soil conditions
- EPA datasets for discovering brownfield conditions, previous environmental contamination
- Demographics for business feasibility

Land Planning: GNSS Surveying and Geodetic Applications

One of the most common uses for *GNSS systems is the performance of topographical surveys and the production of maps. Simple handheld GNSS Receivers usually do not have the required level of precision for many surveying requirements; however most of these specific requirements can be met using high-end, dual frequency, multi-constellation receivers or transceivers (image), built specifically for surveying and through the use of GNSS augmentation techniques.

The use of GNSS techniques in geodesy have completely changed the way geodetic measurements are performed. GNSS measurements have become the basis for nearly all of the geodetic networks.

**GNSS (Global Navigation Satellite System) is a satellite system which is used for establishing the precise geographic spatial location of a user's receiver.*



Total Station
Image Source: Topcon

Agricultural: Crop Management and Monitoring

GIS agricultural management systems can be used to create more effective and efficient farming practices.

Through the combined datasets of climatic patterns, insect patterns, pesticide and fertilizer dispersal rates, and soil data, various querying and spatial analysis procedures can be applied to determine the answers to various agricultural questions.

Questions such as:

- what are the best crop to plant for a given season
- proper crop rotation sequences (the practice of growing a series of different types of crops to aid in soil erosion reduction and to increase soil fertility and crop yield)
- where they should be planted any in what densities
- when and how much should irrigation be used to supplement rainfall
- how to maintain nutrition levels to best benefit crops
- projected crop production predictions

Satellite Imagery of Kansas Crop Fields
Image Source: Wikipedia.org

Agricultural: Irrigation Resources Management

For areas such as the western states, drought conditions are a recurring concern for those who rely on the availability of irrigation water resources (image) for their livelihoods.

Water availability, for any region with high crop production, needs to be properly and efficiently managed.

To evaluate irrigation system performance, the use of satellite remote sensing and GIS, combined by ground information has been found to be an efficient set of spatial tools for identifying major crops and their conditions, and determining their areal extent and yield.

Irrigation requirements for crops are determined by considering such factors as:

- Evapotranspiration
- Field irrigation Requirements
- Net Irrigation Requirements
- Gross Irrigation Requirements
- Monthly total volumes of water required

Crop Irrigation System
Image Source: ag.purdue.edu

Agricultural: Monitoring of Crop and Forestry Infestation

Monitoring of Bugs

The monitoring and control of various types of infestation populations is vital to industries such as forestry and agriculture, to public health, or to the protection of wildlife species.

Crop Infestation

Most crops these days use pesticides to control crop devouring insect, but it is important to use the correct types of insecticides. Farmers and forestry management officials need to know what threat is upon them in any given year.

GIS is a helpful tool for tracking and quantifying insect populations to provide a rough idea of what type of insect is where.

Hotel Bedbugs

Another industry, the hotel business, is fighting a different type of infestation, bedbugs. As hotels guests come and go, they spread the pesky little creatures from hotel to hotel, and eliminating them requires diligence and professional intervention.

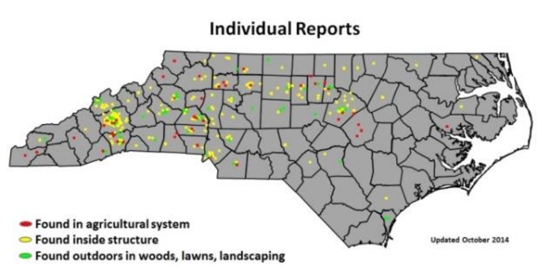
Compiling data from sources such as pest control businesses, health officials, and hotel management is useful when combined with seasonal climate data and tourism patterns.

Deer Ticks and Lyme Disease

The Center for Disease Control (CDC) is tasked with tracking insects such as the deer tick, which is causing an epidemic of Lyme disease in populations through the North and Central East Coast states.

This disease is not only growing in the human species but is also growing within the wildlife and within the insects themselves. It is estimated that the number of deer ticks with Lyme has tripled in the past decade alone.

GIS is a key instrument in tracking clusters of infestations, in order to evaluate how the insects are migrating. Climate data, crop reports, and entomology reports are types of data which can be imported and queried in performing an infestation study.



Monitoring the Brown Marmorated Stink Bug in NC
Image Source: entomology.ces.ncsu.edu

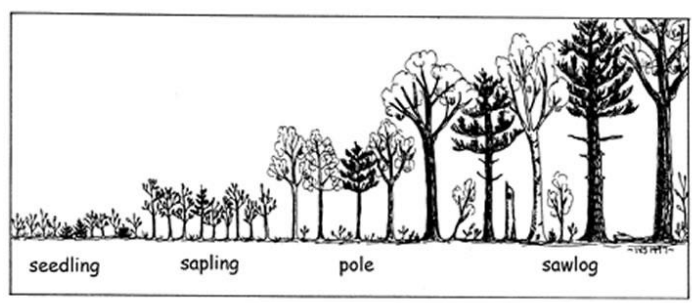
Agricultural: Forestry Inventory Management and Deforestation Monitoring

In many areas of the world these days, forested areas are rapidly decreasing, due to circumstances such as pestilence, acid rain, or human short sightedness which values quick profits over natural resource sustainability.

GIS is efficiently used to monitor the degree of deforestation and map the principal causes for the deforestation process. A variety of data can be queried when analyzing *forest stands and existing forest inventories.

*A forest stand is a contiguous community of trees which is uniform in its composition, structure, age and size class distribution, spatial arrangement, site quality, condition, or location to distinguish it from adjacent communities.

Stand level modeling is a type of GIS based modeling used in the forest sciences, in which the main unit is the forested stand.



Levels of Forest Stand Growth
Image Source: extension.unh.edu

Land Planning: Site Feasibility Studies

In finding the right piece of property to develop a residential PUD, grow Christmas trees, or to build a strip mall, a site feasibility study is usually recommended. GIS is a good way to lay out a thorough feasibility study.

Feasibility studies are preliminary studies undertaken in the very early stages of a construction project.

They are usually a requirement of financiers when a project is large, complex, or where there is some doubt or concerns regarding the proposed development site.

If an environmental impact assessment (EIA) is required, this may involve assessments best undertaken as part of feasibility studies. Phase 1 and 2 site assessments can be included in the study to review the site's potential brownfield, or contamination conditions.

The purpose of a feasibility study is to:

- Establish whether the project is viable
- Help identify feasible options and alternatives
- Assist in the development of other project documentation such as the business plan, project execution plan, and a development strategy brief

On large or complex projects, there may be a number of different feasibility studies carried out, sometimes requiring different skills, and considering issues.

Issues such as:

- Planning permission
- If an environmental impact assessment is needed
- Legal and statutory approvals
- Analysis of the budget relative to client requirements
- Assessment of the potential to re-use existing facilities or doing nothing rather than building new facilities
- Site appraisals, including geotechnical studies, assessment of any contamination, availability of services, uses of adjoining land, easements and restrictive covenants, environmental impact
- Considering different solutions to accessing potential sites
- Analysis of accommodation that might be included or excluded
- Assessment of the possible juxtaposition of accommodation and preparing basic stacking diagrams
- Assess operation and maintenance issues
- Appraisal of servicing strategies
- Procurement options

Feasibility studies can quickly become complex and hard to follow. Therefore the study should be presented in a structured way, so that the client will easily see whether or not to proceed to the next stage.

Wherever possible, any information prepared or obtained should be in a format which can be readily shared and used, and should be stored and named in a way consistent with the long-term project and operational needs.

This is where GIS is able to consolidate all of the above data into easy to read reports, maps, and plans, and provide data analysis capabilities.

Site Comparison Map for Feasibility Study

Image Source: cchsbuilding.org

Land Planning: Cadastral Management and Planning

Cadastre is generally defined as the registering and management of legal titling, land descriptions (metes and bounds) and the taxation of land parcels.

Cadastral information is of vital importance in most countries, as it provides the basis for efficient real estate title management and property taxation based on appraised land values. Implementing cadastral mapping or updating the data is a massive undertaking for local governments.

Accuracy in both geographical and information terms is a considerable challenge, and is extremely important when maintaining an accurate, efficient and useable dataset.

Chapter 6: Uses for GIS in Infrastructure Management

Utilities: Gas Distribution Infrastructure

Most utilities use GIS type management systems for the real time monitoring and control of their distribution infrastructure; and natural gas transmission and distribution networks are no different.

Natural gas is initially gathered from the ground at production wells, and from there it is piped to processing facilities where water and natural gas liquids (propane, butane, etc.) are removed from the raw gas stream and prepared for transport.

Natural gas is then stored in underground aquifers, tapped-out oil and gas fields, or in salt caverns allowing the supply to be sequestered until times of peak demand.

From there, large diameter pipelines are used to transport gas from producing areas directly to large customers such as power plant facilities or to local distributor storage tanks.

GIS helps in the oversight of all phases of gas production, from initial oil exploration ventures, to managing of the customer base.

Utilities: Electrical Grid Planning and Monitoring

The national electrical grid is a complicated distribution network consisting of a multitude of switches, relays, switchgears, poles, transformers, cutoffs, cabling, and insulators.

This complex system of power distribution, monitoring and control devices requires the means in which to be handled from a centralized, remote location.

The electrical grid has long been controlled remotely with devices such as annunciators, and electro-mechanical relays, and such. In present times though, SCADA has become the means in which the grid is monitored and controlled. SCADA communicates through the use of computerized control devices like PLCs (Programmable Logic Controllers), HMI (Human Machine Interfaces), and RTUs (remote terminal units).

With the addition of these computerized control components, the grid is evolving toward the status of being a “Smartgrid”.

The term Smartgrid doesn’t actually refer to the grid itself, but an ambitious concept of an electrical delivery system with built-in intelligence features, designed to manage loads more effectively, provide a more automated process to restoring power outages, and to enable more interaction between power providers and the end consumer.

In order to monitor, administrate, and control that many devices, and miles of distribution line, substations, and power generation plants, requires a computer program such as GIS to oversee it.

GIS allows system designers to incorporate the attributes and spatial database features which give the Smartgrid its intelligences capabilities.

By using grid-specific GIS systems such as Smallworld, by GE, all of the millions of devices, poles, and so forth, can be represented by a topological data structure, linked with geodatabases and queried to analyze the entire system for purposes

Purposes such as:

- Bills of materials
- Network nodal, superposition, and mesh analyses (power transients, voltage drops, switching schemes, etc.)
- Quantity counts
- Outdated components
- Network efficiency
- Etc.

Nigerian Power Pole with Illegal Taps
Image Source: voanews.com

Utilities: Advanced Metering Infrastructure

AMI's are found in many types of utility networks these days. These are systems that measure, collect, and analyze household usage, and communicate feedback to devices
For example:

- electricity meters
- gas meters
- heat meters
- water meters

They can provide feedback either by request, or through an automated command. Governmental agencies and utilities are turning toward advanced metering infrastructure (AMI) systems as part of the larger "Smart Grid" initiatives.

AMI differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter. Systems which are only capable of meter reading do not qualify as AMI systems.

An AMI system extends currently used advanced meter reading (AMR) technology by providing two way meter communications, allowing digital commands to be addressed to the households for purposes such as:

- time-of-use pricing information
- demand-response actions
- remote service disconnects

Wireless technologies are critical elements of the "Neighborhood Area Network" (NAN), composed of a mesh configuration of hundreds to thousands of residentially and commercially located meters, similar in nature to broadband LANs and WANs.

Utilities: Locating of Underground Pipe and Cabling

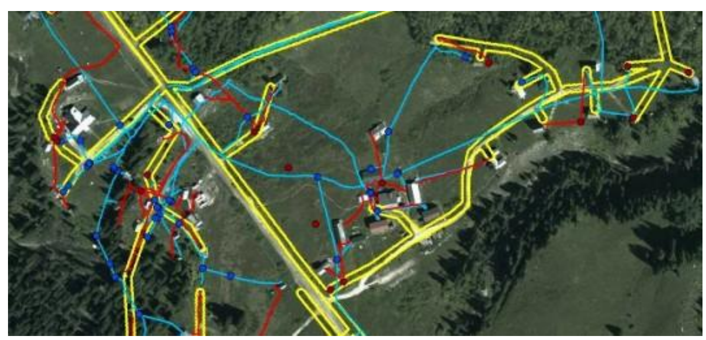
Being able to properly locate underground utilities is essential for a number of reasons such as detecting leaks in gas and water, or wastewater lines, or avoiding digging into high voltage wiring or low voltage cabling.

GIS tools provide an excellent means for a preliminary visualization of underground utility dangers (image).

Many times this map data may be incorrect or slightly off, requiring the services of a qualified underground utility locating service to find and visibly mark the location of every buried utility.

The uses of metal detectors are suitable for a handful of utility runs, but drainage lines and irrigation systems often contain no metal. Also electric wires can be deeper than a standard metal detector can sense.

To find all types of items that can be buried, most underground utility locating services use Ground Penetrating Radar (GPR) equipment to be safe.



GIS Map of Various Utilities
Image Source: undergrounddetective.com

Utilities: Telecom and Cabling Network Management

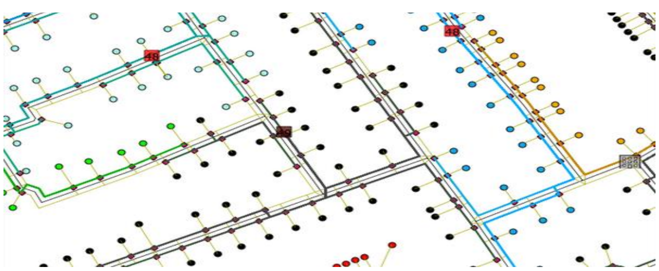
Telecom providers utilize GIS systems which integrate spatial data for managing a variety of uses such as: marketing and demand forecasting, network engineering, customer management, system maintenance, and technician fleet management.

Telecommunications companies are able to use GIS to help them forecast the demand for their services. Both targeting customers and predicting where and when growth will occur involves integrating corporate reports, demographic data, and predicting potential growth in the customer base.

GIS-based operational support systems make sure that the communication network functions properly, with activities such as network monitoring, outage management, billing, and testing.

Intelligent features modeled in CAD (image) and GIS can incorporate attributtal data and "rules" that speed the design process, provide feedback on the status of the network components, and allow querying to identify features in a network element layer such as switches, relays, amplifiers, filters, etc. for total network analysis and monitoring.

The ability to anticipate problems and prevent outages before they occur is another tool that enables carriers to be more competitive and reduce costs.



Fiber Optics Network with Drop, Feeder, and Distribution Layers
Image Source: consof.com

Utilities: Water and Wastewater Infrastructure

Municipal water supply is provided to customers through a network of force mains, distribution piping, valves, and other assorted piping fixtures.

GIS systems allow water companies remote control and monitoring capabilities, similar in nature to the electrical grid's SCADA equipment. Metering and data collection of water supplies is accomplished by an (AMI) or Advanced Metering Infrastructure.

Oil Exploration

Geological Industries: Oil Exploration
With the recent boom in US oil exploration, GIS has had an enormous part to play among the various new exploration and recovery technologies, all of which have allowed for previously played-out oil fields to begin producing again.

Uses for GIS in oil exploration include:

Geological Data maps

One of the most common uses of GIS in the petroleum industry is in providing digital map compositions which clearly display geological data, well, and drillhole imagery to petroleum engineers, which can show a 3-D subterranean view of the various processes occurring beneath the surface.

Well planning

With the increase of nonconventional oil resources such as shale gas, shale oil and coal bed methane, GIS is increasingly being used to plan and establish new wells.

GIS can be used to plan well pad patterns around multiple surface drilling constraints, and optimize drilling patterns to calculate the most efficient drilling configuration.

Block ranking

GIS provides an excellent means in which to quickly evaluate and grade oil and gas licenses or lease blocks. It provides a way to mine large amounts of varying data types, in order to improve decision-making, giving companies a competitive edge in the acquisition of licenses.

Drone-based field operations

An emerging use of GIS is in the use of drones or UAVs to remotely sense on-demand high resolution imagery across a proposed or existing oil field. This allows regular monitoring of sites, to identify and manage change, without having to commission expensive satellite data capture or airplane imagery.

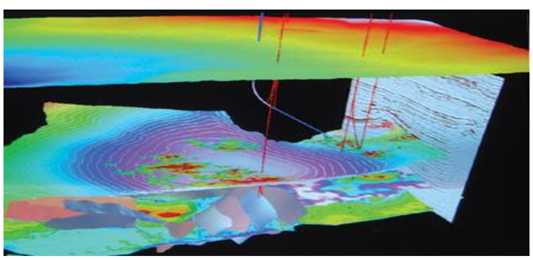
Land Acquisitions and Management

By storing data as attributes, key lease data such as lessor names, lease expiry dates, working interests, overriding royalty, overriding royalty interest, net revenue interest and gross/net acreages can be mapped out for land specialists.

Also, by organizing all land management data in an enterprise incorporated GIS system helps when generating the reports that are required by federal regulators.

Oil Tanker Tracking

GIS in combination with GPS transmitters, can be useful for tracking oil transportation assets, such as land and sea based tankers. Knowing the exact location of vehicles and vessels is essential for the efficient delivery of oil products and services, as well as for efficient emergency response in the event of a spillage incident.



3D Seismic Data Results
Image Source: quantum-er.net

Geological Industries: Mining Industry Assets Management

3D modeling and GIS analysis tools have become a powerful combination of design and analysis instruments, used in exploration and assets management for the mining industry.

There have been a broad range of spatial, property, topological, structural, and statistical query and analysis tools developed to help visualize, analyze, and query geological data sources for mining applications.

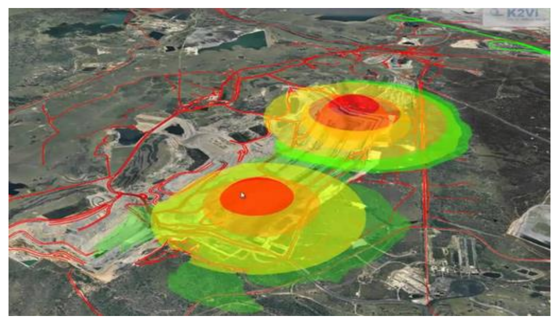
GIS allows mining engineers and geologists the ability to quickly and accurately interpret drillhole data, geological surface and block model data, as well as geophysical and geochemical data.

With GIS capabilities, mining industry engineers can evaluate the structural integrity of the geological strata and the atmospheric components of the mine network, helping to mitigate safety concerns, thus potentially saving the lives of those working in the mines.

Blast Zones

One application illustrated below (image) shows the use of GIS in evaluating the effects of blasting on surrounding features, such as a local highway.

By using GIS with elevational data, the software is able to model the sound wave propagation of the blast over the local terrain.



Mining Blast Zones Modeled within GIS
Image Source: AMM GIS Mining

Pipeline Inspections and Cleaning Operations

Pipelines need to be continually monitored in order to catch leaks and mitigate any potential environmental hazards which may result.

Also there is the need to routinely manage and track inspections, for regulatory compliance. GIS and GPS technologies can play a big part in all of these processes.

Video Logging

Another possible use of GIS is in integrating the map with real-time video logging, using remote vehicles outfitted with GPS equipment. Engineers and inspectors can examine the exterior of the pipeline or the interior by attaching the camera equipment to pigging equipment.

Pipeline Pigging (image)

This process can be aided by GIS, as well. Pigging refers to the practice of using devices called "pigs" to perform various maintenance operations on a pipeline. This is usually done without stopping the flow of the oil in the pipeline. These operations include but are not limited to cleaning and inspecting the pipeline.

Pipeline Pig used for Cleaning and Inspections
(Has a cutaway section for interior viewing)
Image Source: Wikipedia.org

Pipeline Routing Using Least-Cost Path Analysis

Building new pipeline runs is expensive, so determining an optimum route which takes all aspects of the new path into consideration, is critical.

Routing can be simplified through the use of the least-cost path analysis process (identifies the route of least resistance between a source point and destination, based on the effort required to pass through cells in one or more cost raster datasets, such as slope (based on a DEM) and land-cover).

Chapter 7: Uses for GIS in Sales and Business

Marketing, Sales and Demographics

Suppliers: Distribution and Sales Route Management

Large suppliers and specialty products companies can use GIS to manage their sales and distribution routes (image), including sales personnel and vehicular mileage and maintenance logging.

By combining GIS and GPS technologies, linear routing networks can be analyzed to create more efficient distributing of products, or sales solicitation and customer support trips.

This allows for more predictable fleet maintenance scheduling, helping to prolong the life of fleet vehicles, while automatically logging mileages for internal, and external accounting purposes.

Sales Route Optimizing
Image Source: mitsys.com

Demography: (Study of Populations)

The study of demography deals with the statistical analysis of populations, mainly that of human populations. It can analyze any kind of dynamic living population, (one that varies over time or space).

Demographics involve the study of the size, structure, and distribution of these populations, and spatial and/or temporal changes in response to birth, migration, aging, and mortality.

Formal demography is limited to the measurement of population processes, while social demography or population studies includes analyses of the relationships between the economic, social, cultural and biological processes influencing a population.

There are two types of data collection, with a variety of methods of each type; direct and indirect collection.

Direct Data Collection

Direct data comes from sources like the Office of Vital Statistics Registry that tracks:

- Births (Fertility)
- Deaths (Mortality)
- Marriage and Divorce (Legal Status)
- Migration (Changes of Residence)

Census Data

Besides the Office of Vital Statistics, a census is the other common direct method of collecting demographic data. A census is usually conducted by a national government and attempts to enumerate every person in a country.

However, in contrast to vital statistics data, which are collected continuously and summarized on an annual basis, censuses occur only every 10 years or so and thus are not the best source of data on topics such as births or deaths.

Analyses are conducted after a census to estimate how much over or undercounting took place. These compare the sex ratios from the census data to those estimated from natural values and mortality data.

Censuses do more than just count people. They typically collect information about families or households in addition to individual characteristics such as age, sex, marital status, literacy or education, employment status, occupation, and geographical location.

They may also collect data on migration (or place of birth or of previous residence), language, religion, nationality (or ethnicity or race), and citizenship. In countries in which the vital registration system may be incomplete, the censuses are also used as a direct source of information about fertility and mortality; for example the census of China gathers information on births and deaths that occurred in the 18 months prior to the census.

Indirect Data Collection

Indirect Methods

Indirect data collection methods are used in countries or time periods where full data is not available, such as in 3rd world countries or in a study of demographic statistics throughout history.

Indirect methods in present day demographics include asking people about siblings, parents, and children. Other indirect methods are used in historical demography.

Compiling Demographic Data

GIS is very useful for compiling demographic data, of both a contemporary and historical nature, as each has the element of spatial as well as temporal characteristics. Two governmental sources for GIS Demographics data include the US Census Bureau, and the Office of Vital Statistics.

Promoting Tourism

Both GIS and the tourism industry share a common set of characteristics. Both fields have aspects which involve geographical implications, and thus, GIS applications can easily be applied to the promotion of tourism.

GIS applications can provide at least three different types of information for the tourism business:

- *Tourism Resource Visualization Maps* – allows tourism planners and stakeholders the ability to visualize the region's tourist-related resources to see what may be of interest and appeal to potential visitors to the area. It helps in determining the capacity of an area for fun; identifying suitable points of interest and enjoyable activities for newcomers to experience.
- *Tourism Land Use Maps* – helps in analyzing the tourism resources to evaluate land use options and identify zones of conflict or complement, such as access points, water, wildlife habitats etc.
- *Tourism Planning Maps* – allows for the planning and analyzing of the tourism resources, to evaluate the potential tourism industries which may be created in the area.

Sales: Mailing Lists, and Zone Marketing

Geocoding and GIS can be an effective combination of marketing tools when companies need to initiate a mass marketing campaign.

By using buffering analysis, companies can locate all customers within a given range, and cross reference customer sales trends to find the appropriate customers to mail flyers, coupons, and promotional items.

By gathering existing customer data through the use of frequent user cards, credit card sales, or discounting cards, companies can find out what their customers buying habits are, and solicit them accordingly.

GIS is an effective means in which to display and visually analyze the thousands of data fields gathered from these types of marketing tactics.

Sales: Economic Development and Business Feasibility Studies

GIS technology is a valuable tool to use in economic development and performing feasibility studies. It helps in the processes of spotting new sales trends, site selection, demographics, suitability analysis, and for finding the right places to establish new businesses or expand existing ventures.

Retail companies such as Starbucks, Outback, and Barnes and Noble do not randomly pick a spot on the map when they expand their chain of stores. Careful planning goes into establishing just the right location to establish a store, (as stockholders do not respond well to store closings).

A GIS system can help to visualize a wide range of datasets, to obtain insight into where a particular store will perform well in the present, or future.

Datasets such as these are typically used:

- Census data
- Typical spending habits of locals (such as trendy items or functional items)
- Irregular or seasonal buying habits (such as snowmobiles, fishing gear, heaters, generators, etc.)
- Income and age clusters
- Types of existing competitors
- Types of successful, existing businesses
- Analyses of regions with limited competition for certain business types

Online Businesses: Product Tracking, Logistics, and Order Fulfillment

Large corporations such as Amazon, Best Buys, and Walmart do a great deal of their business through annual online sales. In order to monitor, evaluate, and manage these online sales requires a highly sophisticated data and operations management system such as a GIS.

To efficiently fulfill these sales in a timely fashion requires a coordinated effort from the manufacturing, to packaging, to distribution, to processing returns.

GIS can track and map regions of late deliveries, high return rates, damaged freight, and where the high unsatisfied customer percentages appear. GIS is a great tool to use in quality assurance, and quality control.

Business and Finance: Assets Management

Businesses can use their GIS systems to track and monitor various assets within the organization. Regardless of the type of business, nearly any asset can be visualized geographically to some degree. Whether its point data, liner data, or polygon data, most any asset can be shown on maps, and analyzed within the topological data structure.

Types of point data are:

- Business locations
- Competitor business locations
- Supplier's business locations
- Customer locations

Types of linear data are:

- Distribution routes
- Logistical pathways
- Sales routes

Types of polygon data are:

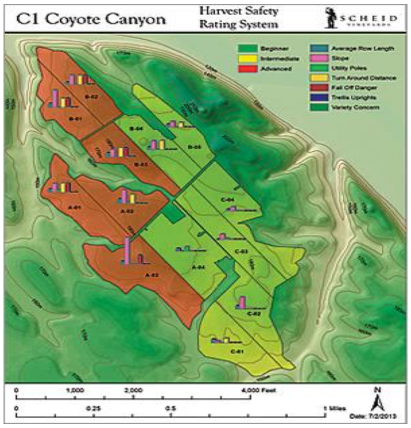
- Sales regions
- Demographical regions
- Marketing regions

Farming and Agricultural: Vineyard Operations Management

GIS is the backbone of an optimally run agricultural operation. A properly organized GIS system can be used for overseeing a farming operation such as a winery; bringing all of the complex facets of a modern day agricultural business into one place.

Various GIS operations which can be performed are:

- the irrigation system network with related valves, sensors, heads, diverters, etc.
- frost zone mapping
- soil mapping and pH monitoring
- future harvest projections and historical harvests analyses
- verifying vine count for each block
- oversee cask management and the aging processes
- compile various data and output reports
- monitor fertilizer rates
- monitor insect infestations and pesticide types and rates



Harvest Safety Rating Map
Image Source: ESRI.com

Business: Banking Mortgage Default Rate Studies

GIS systems can be used for the banking industry to evaluate and visual the default rate potential in their housing portfolios.

By analyzing the clusters of foreclosures over time, bankers can establish distributional and cyclical patterns of economic instability, evaluate potential boom and bust cycles, and create profiles of community neighborhood characteristics.

Datasets such as historical default incidences, census tract data, and loan profiles, can all paint a picture of the root causes of high default rates, allowing financial officers to mitigate future loan defaults, by reducing high risk inventory.

Typical loan data which could be used are:

- typical loan to values
- interest rates
- prime or subprime
- income types and annual salaries of the typical default borrower
- second and third mortgages
- debt ratios
- credit histories

Chapter 8: Uses for GIS in Real Property Management

The Process of Geocoding

Geocoding – Address Locating

Also known as address-matching, geocoding is the process of assigning locations to addresses (similar to pushing pins into a paper map), for placement as points on a map, and then analyzing those points along with other spatial data.

Two sets of data are required for the geocoding process; the address data that needs to be placed on the map, (such as a mailer list), and the GIS data layer that will be used as the geographic reference layer, (city's street centerlines layer or a parcel address point layer).

Both data sets must be prepared prior to geocoding. Preparation of the address data set requires formatting the information properly so that the GIS software can process it. This process is commonly known as parsing.

A typical geocoding process would include:

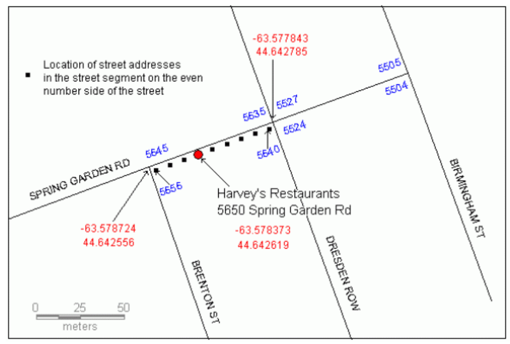
- *In the data list (Address Data)* - might include a physical address, such as 1313 Mockingbird Ln.
- *Road segment centerline (in the GIS data layer):* there would be a linear road segment which corresponded to the 1300 block of Mockingbird Ln.
- *Result of geocoding:* would be a feature point placed somewhere along the odd-address side of that road segment (image).

The data set should be in a database compatible format like comma-delimited (.csv) or tab-delimited (.tab) text file or dBase (.dbf) or in an Excel worksheet.

The address should be contained in a single column that contains the street number and street name, as well as the street's prefix or suffix direction (N,S,E,W), street type (ex. -Ln. or Blvd.). Intersection descriptions (for example, "Hopkins Blvd. & Rosie St.") can also be included in this field.

There are many uses for geocoding such as business locating, for example, or to find out what exists at a particular location.

A location can be described in many ways, using, for instance, name of place, post code, or geographic reference such as longitude or latitude or X, Y coordinates.



Geocoding Data Structure
Image Source: directionsmagcom

Real Estate: Properties and Facilities Management

Many larger commercial buildings and industrial facilities are being built as “Smart Buildings” these days.

Much of the day to day operations of these buildings are automatically controlled and monitored, such as climate control, lighting, security and fire protection, surveillance, and badge access control (secure area hierarchy).

The combined use of BIM and GIS allows for better building, site and real property design, use and management.

Facility-specific templates and applications can be integrated with leading facilities software to provide a solution for mapping both inside and outside buildings.

If the building model is initially designed in a (BIM) or building information modeling, much of the automated functionality framework will already be constructed in the 3D model.

Various types of facility management software programs:

IWMS (Integrated Workplace Management System)

This is a software platform that allows organizations to optimize the use of workplace resources, including the managing of a company's real estate portfolio, infrastructure, or facility assets.

CMMS (Computerized Maintenance Management Systems)

These software suites are used by an organization that must perform maintenance on equipment, assets and property.

Some CMMS products are for general, “out of the box” use, while others focus on specific industry sectors, such as the maintenance of fishing fleets, or equipment in a food processing facility.

CAFM (Computer Aided Facility Management)

This is the support of facility management through the use of information technology. The supply of information about the facilities is the focus of this system.

EAM (Enterprise Asset Management)

is the optimized life cycle management of the portfolio of physical assets contained within an organization.

EAM manages the design, construction, commissioning and decommissioning, operations, maintenance, and replacement of enterprise equipment and facilities.

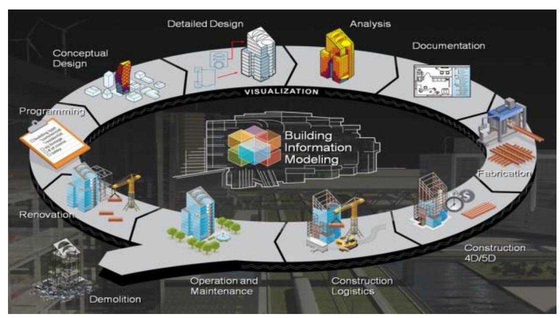
ERP (Enterprise Resource Planning)

This is a category of business-management software, usually a suite of integrated applications, which an enterprise can use to collect, store, manage and interpret data from many business activities, including: product planning, cost, manufacturing or service delivery, marketing and sales.

GIS tends to be used more for managing the exterior assets of an organization or enterprise. When assets are distributed over a single large site, or throughout various cities, states, or countries, GIS can help manage, monitor, and analyze all of the spread out components, in one integral, spatial model.

GIS can help a real estate assets management organization plan for and manage facilities in these three ways:

- *Portfolio:* Manage all related assets including: land, infrastructure, structures, and office space planning and layout design
- *Operations:* Track and manage all real estate assets by location for organized, streamlined work flow
- *Safety and Security:* Provide a safe, overall environment for assets through better allocation of resources and ensuring safety and security compliance.



Operations within a BIM System
Image Source: directionsmag.com

BIM: Space Management and Planning

Space planning (image) is an integral component of the interior design process, for designers and consultants. In the process of space planning, the designer creates polygonal “smart” regions which are representative of interior spatial areas, which are linked to attributtal data within a database.

When large facilities and commercial buildings are completely outlined with these polygonal regions, the model can then be used for querying and spatial analysis of various data fields, depending on the attributtal data which has been incorporated into the model.

Multiple polygonal areas can be overlaid, to provide a rich mixture of thematic mapping schemes.

Typical features which are arranged within a space plan are:

- Furniture
- Furnishings
- Equipment
- Cabinetry
- Appliances
- Modular wall sections
- Partition walls
- Plants

In addition to polygon features, linear and point features can be used in the BIM model, such as MEP networks (mechanical, electrical, plumbing), communication systems, control networks, etc.

GIS helps facility administrators to organize and spatially visualize industrial facilities and commercial building space, for deducing how the spaces can best be optimized. Operational and overhead expenses can be reduced, through a more efficient use of interior spaces.

The 3D visualizing in GIS platforms can provide planners with an interactive experience, like a virtual walkthrough of the building and rooms prior to a construction or renovation project.

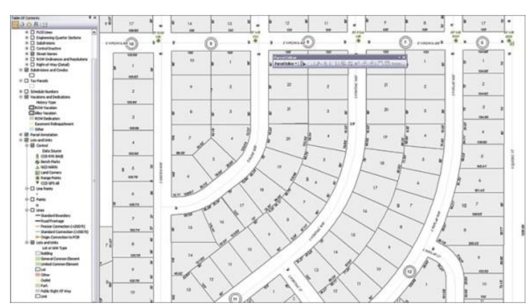
BIM is the vector based CAD modeling platform of choice for the initial construction of a 3D structure model. Once a structure is constructed in BIM, it can be incorporated into a GIS model for a more complete, whole site 3D analysis experience.

Space Planning Diagram for a Dentist's Office
Image Source: vdbg.com

Real Estate: Parcel Data Layers
Most county GIS systems are primarily used for managing of parcel data (image). Parcels can be delineated with closed loop polygons, which can contain linked attributtal data fields for a variety of property parameters.

Some of the parcel data types which can be queried are:

- Parcel ID and description
- Deed page, book, and plat map info
- Appraisal and valuation data for land and structures
- Fire and school districts
- Metes and bounds, and legal description
- Owner name and address
- Property address
- Title and deed type
- Tax data and MIL rates
- Unique identifier numbers
- Raster image of structures and land



Parcel layers in GIS
Image Source: ESRI.com

Real Estate: Data layers for Zoning and Land Use Requirements

Zoning is a means for local governments to designate and regulate what is allowable on a given parcel of land. Most GIS systems which deal with land will have layers specifically for zoning boundary delineation.

Zoning guidelines are a general rule of thumb for a parcel's proposed use, which can usually be superseded when necessary, by the use of land variances. Land variances usually require a certain degree of legal action, and approval amongst neighboring land owners.

The word "zoning" is derived from the designation of allowable uses for land, based on mapped zones which separate one set of land uses from another.

Zoning may be based on land usage (regulating the uses of the property, such as agricultural, commercial, industrial, or residential), or it may regulate structure heights (structures not to exceed 35 ft.), lot coverage, interior structure areas (such as R-11; no residential structures less than 1100 square feet), and similar characteristics, or some combinations thereof.

Some zoning regulations dictate business prohibitions (such as parking requirements, alcoholic sales related, adult themed, or noise limitations).

Zoning Types in the United States

Zoning Categories

Various approaches to zoning can be divided into four broad categories:

- Euclidean
- Performance
- Incentive
- Form based

Standard Euclidean Zoning

Named for the type of zoning code adopted in the town of Euclid, Ohio, and approved by the US Supreme Court, Euclidean zoning codes are the most prevalent in the US, used in both small and large municipalities.

Euclidean zoning

Euclidean zoning is used by so many municipalities due to the fact that it is effective, easy to implement (with one set of explicit, prescriptive rules), has a long established legal precedent, and familiar to planning and design professionals.

However, Euclidean zoning receives criticism for its lack of flexibility, and institutionalization of its presently outdated planning theory.

Euclidean zoning is characterized by the division of land uses into specific geographic districts and dimensional standards which set limitations on the amount of development activity that is allowed to take place on lots within each land use district. *Typical types of land-use districts in Euclidean zoning are:*

- Manufactured homes
- Single-family residential
- Multi-family residential
- Commercial
- Industrial
- Agricultural

Uses within each district usually exclude other types of uses (such as residential districts disallowing commercial or industrial use).

The occasional conditional or "upgrade" use may be permitted in order to accommodate the needs of the primary land use, for example manufactured home zoning usually allows stick-built structures as well.

Dimensional standards apply to structures built on parcels within each zoning district, in the form of setbacks, height limitations, minimal lot sizes, lot coverage limits, and limitations on the building envelope.

Euclidean II Zoning

Euclidean II zoning uses traditional Euclidean zoning classifications, but establishes them in a hierarchical order, nesting one zone class into another, (similar to Planned Unit Development, or PUD mixed use applications).

For example, multi-family may be permitted in a higher order multi-family zone, as well as permitted in high order commercial and industrial zoning districts.

It is relatively easy to transition from most existing zoning classification systems to the Euclidean II Zoning system.

Protection of land values is maintained by stratifying the zoning districts into levels according to their location in the urban hierarchy (neighborhood, community, municipality, and region).

Euclidean II zoning also incorporates transportation and utilities as new zoning districts, dividing zoning into three categories:

- Public
- Semi-Public
- Private

Euclidean II zoning promotes the concept of mixed use, new urbanism or highest and best use; and simplifies zoning classifications into a single and uniform set of activities.

Performance Zoning

Performance zoning often utilizes a "points-based" system whereby a property developer can apply credits toward meeting established zoning goals through selecting from a 'menu' of compliance options, like: mitigation of environmental impacts, providing public amenities, building affordable housing units, etc.).

Incentive Zoning

Incentive zoning is intended to provide a reward-based system to encourage development that meets established urban development goals.

Typically, a primary level of prescriptive limitations on development will be established, with a secondary list of incentive criteria for developers to adopt or not at their discretion.

A reward scale connected to the incentive criteria provides an enticement for developers to incorporate the desired development criteria into their projects. Some examples are floor-area-ratio bonuses for affordable housing provided on-site, or height limit bonuses for including on-site public amenities.

Form-based Zoning

Form-based codes offer considerably more flexibility in building uses than those of Euclidean codes.

Form based zoning regulates the form that a given land use might take. For example, form based zoning in a dense area may call on small setback limits, high density, and pedestrian accessibility requirements. Or, in a suburban single family residential area, uses such as offices, retail, or light industrial might be permitted.

Form-based zoning relies on rules applied to development sites according to either prescriptive or discretionary criteria. These criteria are normally dependent upon lot size, location, proximity, and other specific characteristics.

Real Estate: Mass Property Appraisals

Property tax appraisers have the unenviable task of assessing value for huge numbers of real estate parcels in relatively short periods of time.

GIS is very useful for the accessing of values through the use of spatial analysis techniques such as buffering, overlay, adjacency and connectivity.

Various mass appraisal models exist, such as Hedonic models, which are essentially a regression technique; or the (OLS) model Ordinary Least Squares which has been widely used in mass appraisal to estimate the value of the property market in USA.

In the GIS, spatial land parcel data can be linked to attributtal data located in a Computer Assisted

Mass Appraisal (CAMA) geodatabase system, which stores the tabular information for all of the real property.

Real Estate: Tax Jurisdiction Data Layers

Tax jurisdiction districting maps are a common layer found in many GIS systems. Each state is divided into tax jurisdictions to determine sales, property, and other use taxes imposed within that given jurisdiction. Jurisdictions are established at the state level, with tax rates varying based on location. Some states may also require separate taxation within special zones, such as school district boundaries.

The cadastral (tax assessment) data for a county, is maintained by the county tax assessor's office. Assessors do not determine tax (mil) rates, or bear the responsibility of collecting tax revenues. Their purpose is more the valuation of real property, for taxation purposes.

Property taxes are the major source of revenue that allows local governments to provide community services such as public education, or fire, ambulatory, and law enforcement services.

Hand drafted tax maps were difficult to keep current and storage or retrieve was troublesome; also multiple copies of maps sometimes contained conflicting data.

In present time, tax maps are maintained as part of a GIS, making them easier to update, organize, and share amongst governmental departments.

Chapter 9: Uses for GIS in Government and Defense

Overview

Military: Intelligence, Surveillance, and Recon (ISR)

During a military engagement, access to real time ISR assets is crucial to the success of the mission. The ability to quickly overlay battle field data into a map is an important capability for military analysis of the battlefield environment.

Based on live geographic data, reports and intelligence information can be combined to visualize threats and respond to emerging situations.

GIS can provide the following ISR support and interactive features:

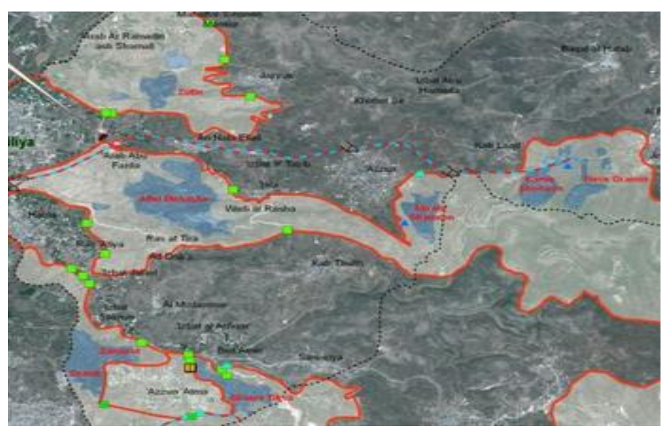
- Use maps with dynamic data sources to provide real-time operational views
- Build interactive maps
- Watch real-time data feeds
- Compile lists, charts, gauges, and other performance indicators views
- Track assets
- Monitor indicators and receive warnings
- Assess battle damage and coordinate support
- Data synchronization in near real time to help make faster and smarter decisions
- View information in a dashboard using an operational picture defined to fit a specific mission,
- Analyze patterns, examine relationships, and determine probabilities using tools and templates
- Combine data from multiple sources to create change detection, incident analyses, and other intelligence information and products
- Create powerful custom image analysis routines

Military: Command and Control

Nearly all governmental defense agencies use GIS for managing field movements and for overseeing their military forces. Militaries rely on the geospatial awareness a GIS system provides, from mission command to intelligence, surveillance or recon (ISR).

GIS is able to provide:

- newly acquired battle field vector and raster datasets assessments
- line-of-sight, battlefield assessments
- Military Grid Reference System (MGRS) conversions
- analysis of Digital Terrain Elevation Data (DTED)
- aerial and ground travel time and fuel ranges
- weaponry systems assistance
- munitions efficiency assessments
- overlays for ISR data in near real time
- Vehicle tracking
- Safety and security oversight
- Monitoring of critical infrastructure and high-risk targets
- Friendly, non-friendly, and civilian clusters displays
- Unexploded ordinance area coordination and remediation



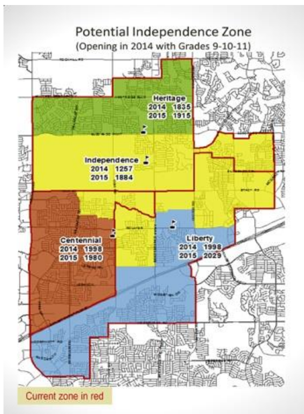
Military Map Composite
Image Source: ESRI

Governmental: Schools Re-Districting

As a student population varies from year to year, or as new schools are opened and existing schools closed, local communities are routinely required to re-district their school boundaries (image).

When provided with student address locational data, geocoding makes it much easier to evaluate potential re-districting scenarios. By entering proposed boundary changes, student headcounts, by grade, can be reconfigured.

While school departments have always done it this way to some extent, GIS software makes proposed boundary reevaluations much more efficient.



Map of School Districting
Image Source: Friscoisd.org

Governmental: Schools Busing and Pedestrian Analysis

When deciding on the eligibility of students for busing, GIS can be used to determine which addresses qualify for busing privileges. This is accomplished through the use of GIS geocoding capabilities.

Also, by using property boundaries and school boundaries, a geodatabase can be developed which designates student eligibilities for magnet school participation. Busing routes can be analyzed to find the most appropriate routes, and figure out where congestion occurs, and child safety issues can arise due to stopped buses.

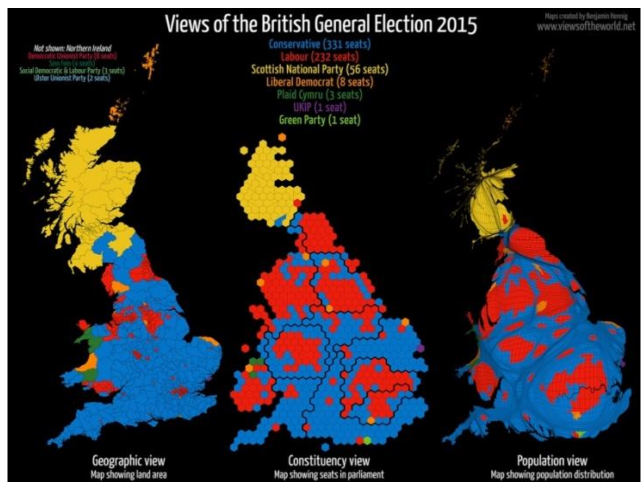
For those children that walk to school, walking distance parameters can be compiled, which analyze average distances walked, routes typically taken, etc. in order to designate and budget for suitable crosswalks with attendants, and identify any potential safety issues for the children.

School Bus Routing Applications
Image Source: wikipedia.org

Governmental: Election Mapping

Politicians running for office can use GIS data for gaining feedback from various sources such as compiling maps which show polling numbers from particular voting districts, or for comprising statistical data for campaigning purposes.

Media sources can also use GIS for displaying election and survey results, or to illustrate statistical data (image) relating to the elections process.



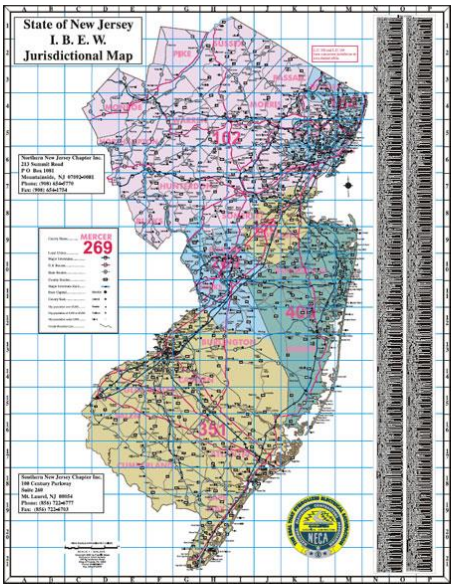
Elections map of the 2015 UK General Election
Image Source: viewsoftheworld.net

Governmental: Jurisdictional or Precinct Zones

GIS is a handy tool for delineating various jurisdictional regions, and outlining jurisdiction data. Many branches of government and private sector organizations have the need for mapping out various districts and jurisdictions within their hierarchies.

For example, the NYPD is the largest police force in the US, with around 50,000 employees, covering five boroughs, with 76 precincts (typically designated by neighborhood boundaries), with each precinct being divided into sectors, which are further broken down into "beats" which are patrolled by individual uniformed officers.

In order to keep track of the many divisional sections of the city, GIS maps can be very useful in outlining specific criteria for each region.



IBEW Union Jurisdiction Map
Image Source: ibewlocal102.com

Fire Services: Response Distance Analysis
A GIS can be used to evaluate distances of structures from a given firehouse. This can be helpful in evaluating the best construction site for a proposed firehouse.

Additionally, in establishing insurance ratings of residential, industrial, and commercial districts, GIS can help in determining how well an existing fire service covers a particular district, and aid in finding solutions to improve inadequate fire service.

Services can be improved by GIS, through coordination and overlapping of volunteer and municipal fire service districts, and optimizing the response routes.

Law Enforcement: Criminal Incident Mapping and Analysis - Data Layers
Most criminal activity is mapped out these days, with all police calls logged into crime reports based on geocoding data. This data is very helpful when performing analysis such as real estate valuation, demographics, and for law enforcement investigations.

Criminal incidents are usually represented in a GIS layer by point features. This point data can be queried to establish relatable patterns of violent crimes such as assaults and rapes, while property damage or thefts can be assessed for commonalities.

Law Enforcement: Forensics and Trial Presentations
GIS is a very powerful tool in forensics when properly applied. When investigators are seeking to analyze large quantities of data, sometimes GIS can give detectives a clear picture of patterns of human behavior and criminal activities, looking for patterns in Modus Operandi (MO, or methods of operation) within criminal incidents.

Composite maps can also be used in trials for displaying complex data in a way that judges and jurors can easily comprehend.

Spatial analysis can provide a much clearer picture of a crime scene (image) for those without the in depth technical expertise to understand detailed police reports.

CSI Investigator
Image Source: americansentinel.edu

Law Enforcement: School Zone Offenders and Penalization

GIS can be a powerful tool for identifying potential sex and drug dealing offenders living in and around school zones.

Also when drug dealers are caught in the act, in many jurisdictions, there are drug penalization zones, where if an offender is convicted of selling drugs within 1000 feet of a school property, special penalties can apply to their sentencing. GIS software can easily map these buffer zones (image) making it much easier to determine whether a specific arrest location is within the buffer zone.

An additional use of GIS buffering analysis around schools, concerns determining if a proposed business is within a specified distance of a school or religious institution, (for example, adults-only retail or entertainment establishments).

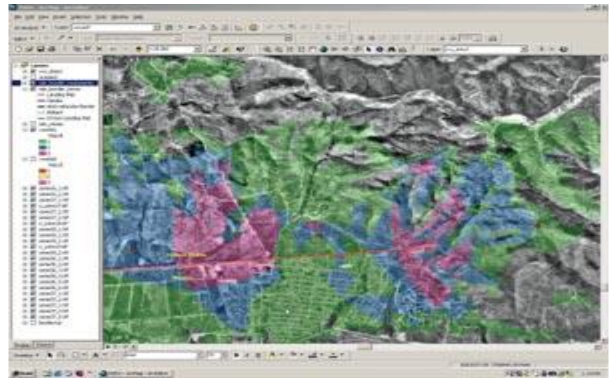
School Buffer Zone

Homeland Security: Border Activity Monitoring

In monitoring an international border, logging and mapping of incidents helps to establish patterns of illegal crossings, criminal activity, offender characterization, and more.

This gives border patrol officers a better picture of who is doing what and where. By combining data gathered automatically from sensory devices and cameras, or infrared imagery, security analysts are able to determine where to focus patrols within the thousands of miles of border.

Through the use of viewshed analysis techniques (image), DEM terrain images can be analyzed to find proper observation points to identify blind spots in video surveillance.



Viewshed Analysis of a Border
(Used to analyze the placement of cameras)
Image Source: ESRI.com

Social Services: Sociology and Behavioral Studies

GIS is one of the most value tools available for the study of sociological, cultural, human interaction and behavioral patterns.

Spatial patterns in social data reveal issues and trends that would otherwise be missed by other means. Social scientists have recently begun to better appreciate the correlation of social phenomena and location, viewing the effects of environment on human behavior.

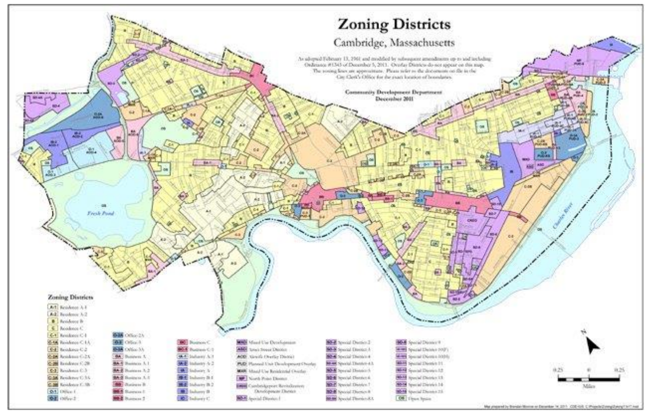
Ways that sociologist can use geographical data to map human behavior:

- Income inequalities
- Correlation of poverty to other social indicators
- Crime rates (violent and non-violent)
- Disease transmissivity
- Incarceration rates
- Stress related illnesses
- Higher education participation
- Mental illness types and rates
- Violent behavior patterns
- Cultural and ethnical differences
- Purchasing habits
- Morality and religious beliefs
- Linguistical variations
- Mortality rates among varying age groups
- Health, exercise, and dieting habits
- Social vs antisocial behavior patterns (general isolation, alienation vs. a sense of community)

- Gender, ethnicity, race, and age densities and inequalities

City Planning: Urban and Regional Planning and Budgeting

City planners can use GIS technology to research, develop, implement, and monitor the progress of their annual budgeting and planning (image).



Zoning Districts for Cambridge, Massachusetts
Image Source: gislounge.com

GIS provides city planners, administrators, surveyors, and engineers with the tools they need to design and map nearly all of the aspects of community administration. GIS is the most powerful tool that administrators have at their disposal, for making educated decisions on the behalf of the local citizens.

Just a few of the GIS can be used for:

- Capital improvements project (CIP) planning and management
- School Zoning
- Property Accounting Plans
- Parks and Recreation Management
- Infrastructure Management (Water, Wastewater, Roads, Electrical Power Supply)
- Trash Collection Routing and Scheduling
- Cadastral Oversight
- Mass Real Properties Appraisal
- Building Zoning and Permitting
- School Districting
- Voter and Electoral Districting and Management
- Land Use and Ordinate Violation Enforcement
- Establishing of Historical Districts and Revitalization Planning
- Mapping of Urban Inequalities
- Housing and Urban Development Administration
- Brownfield and Environmental Monitoring