

# SUSTAINABLE MINING AND GEOINFORMATION

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Week – 02

## Lecture 06: Geographic Information System (GIS)

Welcome back, so this is the second week, lecture number six. We are going to discuss the geographic information system, abbreviated as GIS. Often, we also know it as the geographical information system. Both of them are used, as you might say, in tandem. So, let us understand the basics of the geographic information system, which involves capturing data, analyzing data, retrieving data, and then giving an output or result in terms of maps and other expressions. That is the starting point of GIS or the geographic information system. It also essentially has a coordinate or reference frame as far as the Earth's geographic system is concerned. So, that means we have a reference to Earth's geography in terms of X, Y, and Z coordinates, which are latitude, longitude, and also the height or altitude elevation.

So, let us have a look at the concepts we are going to cover. The concepts we are going to cover are introduction. So, we will introduce the term GIS. I am sure many of you have already heard this term before. So, introduction to GIS, we will also discuss the basic concepts, the components, and the data types.



The slide features a blue header with the title 'CONCEPTS COVERED' in yellow. To the right is a circular collage of GIS-related images including maps, a person, and a globe. Below the title is a yellow box containing a bulleted list of topics. At the bottom left are the logos of IIT Kharagpur and NPTEL. The footer contains the text 'IIT Kharagpur' and 'NPTEL'.

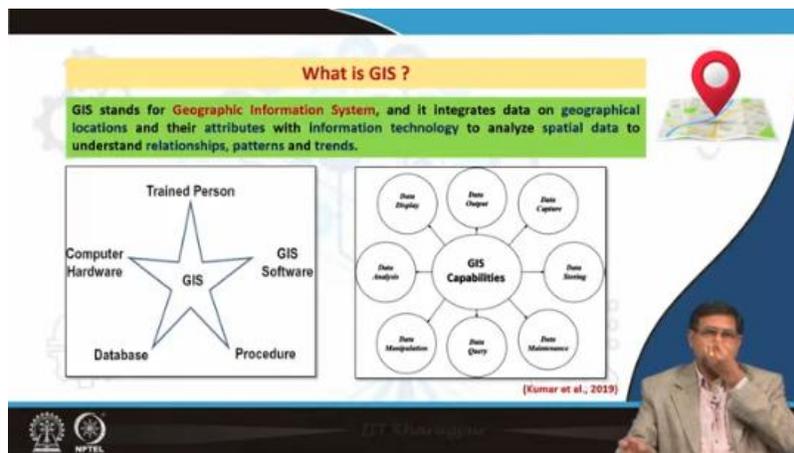
**CONCEPTS COVERED**

- Introduction to GIS: Basic Concepts, Components, and Data Types (Raster, Vector)
- GIS Functionalities: Data Collection, Storage, and Spatial Analysis
- Case Study: GIS Applications in Mine Planning and Environmental Management

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So, the two types of data, basically the raster and vector data types, we will understand them. And the functionalities, as far as GIS is concerned, as I just mentioned, involve the collection of data. Storage of data and analysis, particularly spatial analysis. The moment we talk about spatial, then at least we are talking about X and Y representation, and or Z or the elevation also, if it is three-dimensional. So, the GIS functionality is broadly involved in the collection, storage, and analysis of data.

And also, we will consider one example that involves the application of GIS in mine planning and environmental management. So, what is GIS? On the left-hand side, you are seeing a diagram where in a star we have put on the five different points. One is it involves GIS software, it involves trained manpower, it involves computer hardware, it involves a database, and it involves a procedure. So, GIS involves these five things.



If you say it means, without a computer, we can also do GIS. But then we are putting GIS because all of us in this day are using a computer for GIS. So that means hardware and software involvement is there. And we, as a person or as trained manpower, should understand what it is that we need to do and why we are going to do it. Then we need to follow a procedure, an appropriate procedure, and in the backdrop, there has to be a database, both spatial and non-spatial data, which we are going to talk about.

So, these essentially are the five components involved in or go around the GIS activities. So, GIS integrates data on geographical locations. The moment we say geographical location, as I just mentioned, we need to have X and Y representation. And there are attributes with information technology to analyze spatial data to understand the relationship patterns and trends. So, once we have the data, we can do all these different types of analysis in terms of their pattern, their relation to each other, and the trends they are following.

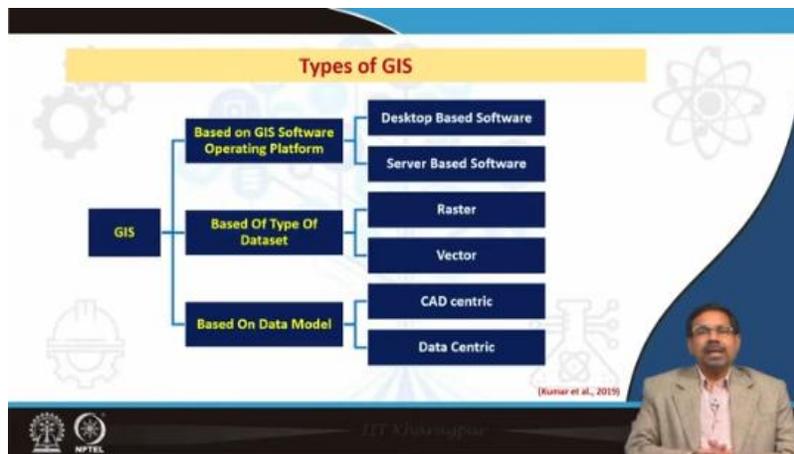
So, this is about the analysis of the data. But then, the important capabilities of GIS. GIS, the important capability could be this: the data capture. So, it captures the data. So, it collects the data.

Then, once the data is collected, it needs to be stored. So, there has to be a proper storage protocol. So, after capturing the data, there has to be a protocol for storing the data. Then, once the data is stored following an appropriate protocol, it needs to be maintained. So, data maintenance is involved.

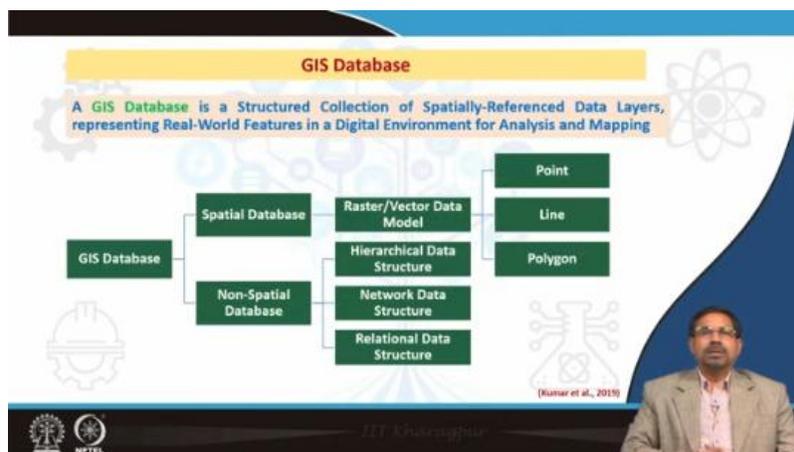
So, once the data is stored and appropriately maintained, we need to analyze the data. So, that means we need to make a lot of queries, we need to give a lot of what you say conditions and criteria. So, we involve the query. So, querying data is another capability. Then, once we do queries on different analyses, that means we are manipulating the data, we are modifying the data, we are making another dataset based on the third dataset we can generate based on the first and second, based on the first, second, and third, we can generate another, the fourth set of data. So, that means we are playing in a data manipulation domain.

Then it all involves the data analysis, and once we have done the data modification, manipulation, and analysis based on different queries and conditions that are based on our requirements, we We would like to see it in the form of a result. So, data display is also important. So, the result and data display, and also the data we are using, we need to display to understand what is there, what has to be done, and what is the output. So, all this finally involves or gives us the output data.

So, basically, the capability of GIS is capturing, storing, maintaining, querying, manipulating, analyzing, displaying, and finally giving an output as far as the data is concerned. So, it broadly deals with the data. And then, types of GIS. So, GIS based on GIS software operating platform. So, based on the operating platforms, we can have desktop-based software, and we can have server-based software.



Based on the type of dataset, we can have raster dataset and vector dataset. We are going to discuss it. And based on the data model, we can have a data-centric model or a CAD-centric data model. So, let us see them one by one. So, first is the GIS database.



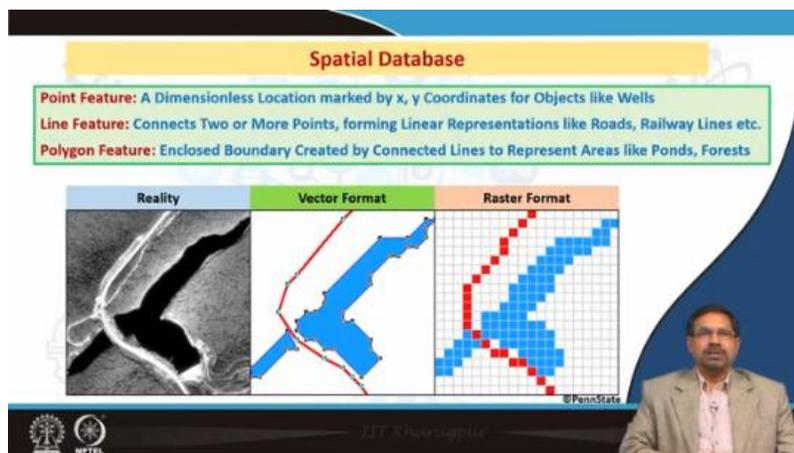
A GIS database is a structured collection of spatially referenced data layers that represent real-world features in a digital environment for analysis and mapping. So, essentially what we are doing is you can also hear the term digital twin. So, essentially the real-world information or the data we are taking into a computational world, an artificial world, a digital world. So, the GIS database, as per the schematic here, can be divided into spatial and non-spatial. Friends, the whole world of datasets can be divided into these two broad categories.

The spatial data, which occupies physical space on our surface, is a geographical entity with x, y, and/or z dimensions. So, they form the spatial data and accordingly, the spatial database. The rest are the non-spatial databases. So, which is also called the attribute

data. So, if a table is a spatial data which occupies space, but the color, the height, and the different properties of the table

go into attribute data or non-spatial data, which we can again attach in this GIS platform to the spatial database. So, always the spatial and non-spatial linkage has to be there using this powerful tool called GIS. So friends, let us talk about the spatial database types. One is raster, another is vector. Raster is generally the grid type, and vector is represented by points, lines, and polygons.

And as far as the non-spatial database is concerned, they can be arranged; the structural arrangement could be of three broad types: hierarchical, network, and relational. So, let us see how they are represented. So, the first is about the data type as far as raster and vector are concerned. As indicated in this diagram, let us see the real world, and in the lower left-hand side figure, we are seeing the real world. Where you have a water body space, you have a road which is passing through, and you have other areas like forest areas around.



So, if we need to represent this in terms of a spatial database, we have two options. One is vector, and another is raster. So, two different data types. So, in vector, we are going to represent them. We have three options.

Either we can represent them in points, or we can represent them in lines, or we can represent them in polygons, or using one or more than one of these representation forms of the vector format. So, point features are dimensionless locations. So, a point is just an entity. A location marked by x, y coordinates for objects like wells and other things. Whereas a line is a linear feature; it connects two or more points.

So, forming a linear representation like roads, railways, and others in a line format. Whereas a polygon is enclosed by a boundary created by connecting lines to represent areas like ponds and forests. So, the middle depiction talks about the representation of this real-world scenario in the form of a vector. We can see the points in the form of dots, the sand-colored dots, the red lines which are the linear or line representation, and the polygon which represents perhaps the water bodies that are shown in the real world. And if we need to represent the same in terms of raster, then look at the right-hand side figure where we are representing the same in the form of raster in terms of the grids.

So, these are the grids, and they represent the red dot grids represent the line or linear features, and the blue dot grids represent the polygon, the water body polygon. So, this is how the representation varies as far as the vector and raster are concerned. So, two things we can very well see from here: the vectors are a very fine representation, whereas the rasters are a very, what you say, coarse or faster representation. That means if you talk about the data quantity or the data accuracy, you can really visualize from here that the vector could be an accurate data format, whereas, in comparison to the raster data, the vector data could be less bulky than that of the raster. So, raster is a heavy data structure, or the data size is heavy as far as the raster is concerned. Now, let us talk about the non-spatial database.

So, the non-spatial database stores attribute data describing the characteristics of spatial features. Hierarchical data structure, network data structure, and the relational. And we have three depictions corresponding to this. As far as the hierarchy is concerned, it organizes the data in the form of a tree-like or parent-child structure from up to down. So, you have a village, you have a block, you have a tehsil of a district.

**Non-Spatial Database**

Non-Spatial Database Stores Attribute Data Describing the Characteristics of Spatial Features

**Hierarchical Data Structure**

It Organizes Data in a Tree-Like Parent-Child Structure with Up and Down Data Access

**Network Data Structure**

It allows Multiple Connections between Nodes, Supporting Complex Relationships with Reduced Redundancy

**Relational Data Structure**

It Stores Data in Tables Linked by Unique Keys, Enabling Flexible Querying & easy Data Management

Block ID	Block Name	Area (Sq. Km)	Population
1	Block A	15000	80000
2	Block B	12000	65000
3	Block C	18000	95000
4	Block D	10000	55000
5	Block E	14000	75000
6	Block F	16000	85000
7	Block G	11000	60000
8	Block H	13000	70000
9	Block I	17000	90000
10	Block J	12000	65000

(Kumar et al., 2019)

So, district number 1, village, block, tehsil. District 2, village, block, tehsil. So, you have a hierarchy like a parent-child kind of relation or a tree kind of relation where a root means each leaf is attached to one small branch, small branches are attached to a big branch, and the big branch is attached to the main bowl. So, that way the tree-like or parent-child structure is followed in a hierarchical data structure. And let us look at the network data structure.

And here in the network, it allows multiple connections, networking. So that means multiple connections between and among the nodes, supporting complex relationships with reduced redundancy. So you have data. 1, 2, 3, 4, 5, 6, and you see how they can be connected, linked, or networked. So, you have different databases from different computers, and you are connecting them using nodes in a complex structural relationship, and you also maintain redundancy reduction.

So, that is what the network data structure is. And then coming to a relational data structure as far as the non-spatial or attribute data is concerned. In the case of the relational data structure, it stores data in tables linked by unique keys, enabling flexible querying and easy data management. So, you have, like, population data, and the population data you are again dividing into SC population, ST population, and different population categories. But then you have one unique ID, or you say the block ID 1, 2, 3, 4, 5, 6.

So, that actually helps as the connecting link. So, the unique key has to be always maintained to link or to relate one data structure with that of the other. So, that way the uniqueness in terms of the relational data structure is maintained. So, let us understand what the vector data analysis is and what are the different things involved as far as the vector data analysis is concerned. So, friends, one is the overlay operations.

**Vector Data Analysis**

<p><b>OVERLAY OPERATIONS</b></p> <ul style="list-style-type: none"> <li>• Polygon-In-Polygon Overlay</li> <li>• Line-In-Polygon Overlay</li> <li>• Point-In Polygon Overlay</li> </ul>	<p><b>LOGICAL OPERATORS</b></p> <ul style="list-style-type: none"> <li>• AND - Intersection</li> <li>• OR - Union</li> <li>• NOT - Inverter</li> <li>• XOR - Difference</li> </ul>
<p><b>SPATIAL JOIN OPERATIONS</b></p> <ul style="list-style-type: none"> <li>• Identity, Intersect, Union, Symmetrical Difference</li> </ul> <p><b>FEATURE EXTRACTION OPERATIONS</b></p> <ul style="list-style-type: none"> <li>• Clip, Erase, Select</li> </ul> <p><b>FEATURE MERGING OPERATIONS</b></p> <ul style="list-style-type: none"> <li>• Dissolve, Eliminate</li> </ul> <p><b>PROXIMAL OPERATION OPERATIONS</b></p> <ul style="list-style-type: none"> <li>• Buffer</li> </ul> <p><b>MAP DATABASE MERGING AND SPLITTING OPERATIONS</b></p> <ul style="list-style-type: none"> <li>• Mapjoin, Split</li> </ul> <p><b>COORDINATE TRANSFORMATION OPERATIONS</b></p> <ul style="list-style-type: none"> <li>• Project, Transform</li> </ul>	<p><b>CONDITIONAL OPERATORS</b></p> <ul style="list-style-type: none"> <li>• EQ = Equal to</li> <li>• NE &lt;&gt; Not equal to</li> <li>• GE &gt;= Greater than or equal to</li> <li>• LE &lt;= Less than or equal to</li> <li>• GT &gt; Greater than</li> <li>• LT &lt; Less than</li> <li>• CN Containing</li> <li>• NC Not containing</li> </ul>

So, in terms of overlay operations, we can have polygon in polygon, line in polygon, and point in polygon. So, when you are overlaying one information above another, with these three geographical entities as far as vector representation is concerned, it can be point in polygon, line in polygon, and polygon in polygon overlay. Now, a few operations which we use very generally, okay. So, generally, we use the spatial join operation to identify, intersect, to make a union between two entities, or to come out with symmetrical differences. Similarly, for feature extraction operations, if we are performing feature extraction, we need to clip something, we need to clip out something, we need to erase something, we need to select or eliminate something.

So, these are the common operations we do during feature extraction. Then, for feature merging operations, we need to dissolve a few features, we need to eliminate a few features. So, these are the merging operations we usually do. So, again, the proximal analysis. So, if something is close by, a buffer kind of activity.

So, a 5-kilometer or 1-kilometer buffer or the surrounding area on both sides of the road or one side of the road. So, that way, singular both-side buffer kind of activities we do or operations we do. Then, coming to the map database merging and splitting operations. So, joining the maps using the command map join, splitting a database. So, we use the command split.

So, these are the very commonly used operations. Coordinate transformation operations. So, we do different because many times what you have the database are in different if you are collecting from different sources, they may be or it is most likely that the database could be in two different coordinate systems. So, you need to transform one to the other so that one can sit over above the other. So, we need to maintain a parlance with respect to the projection system is concerned for that the transformation the coordinate transformation operations are required.

And then we also need to perform some logical operations: AND for intersection, OR for union, NOT for inverter, and XOR for difference. And there are also some operators that talk about the conditional that falls on the conditional category. So, EQ stands for equal to, NE means not equal to, GE for greater than or equal to, this kind of symbols we use. And then CN for containing and NC for not containing. So, some of the conditional operators we use in this way.

So, vector data analysis generally uses a lot of overlays and common operations, for which logical and conditional operations are mostly used in several cases. Then, let us

have a look at the raster data analysis. Friends, the geographical units are represented as grid cells in raster. So, that means each has a specific value representing the geographical units. So, you can say if you are seeing it in terms of variation in temperature, elevation, land use, or land cover, everything has to have a variation at this entity level, which is represented in the form of a grid or a grid cell.

**Raster Data Analysis**

- Geographic units are represented as a Grid of Cells, each with a specific value representing a **Geographic Attribute** (e.g., Elevation, Temperature, Land Use) These cells are of **Equal Size, Identical Shape, regularly spaced and the location of each unit is referenced by Row and Column Positions**
- Every Cell in a Grid is an Individual Unit and must be assigned a value. When data values are NOT Available for Particular Cells, they are Described as **NODATA Cells**

**Map Algebra and Grid Operations**  
Map Algebra is a Core Concept in Raster Analysis involving Mathematical Operations to manipulate Raster Data through **four basic Grid Operations** which are as follows:

- **Local Function:** It works on every single Cell
- **Focal Function:** It processes the data of each cell based on the INFO of a Specified Neighborhood
- **Zonal Function:** It works on Each Group of Cells of Identical Values
- **Global Function:** It works on a Cell Based on the Data of the Entire Grid

The slide also features a grid diagram with a 'Pixel' highlighted in green, and a speaker in the bottom right corner.

So, these cells are of equal size, identical shape, regularly spaced, and the location of each unit is referenced by row and column positions. So, friends, these four points are very important as far as the raster cell properties and their arrangement are concerned. All the raster cells or grid cells have equal size, identical shape, and are regularly spaced. So, the distance between any two is also the same. And most importantly, the location of each unit is represented in terms of rows and columns.

If you have a look at the upper right corner, there is a representation of the grid cell where one pixel is represented in green color. The green cell and all the cells have a representation in terms of rows and columns. So, all these cells, which are arranged in rows and columns, have equal size, identical shape, are regularly spaced, and their representation is also taken care of in a reference frame. And then, every cell in a grid is an individual unit and must be assigned a value. So, that means if it has a value, like the pixel, let us say it is a forest pixel, you assign a value of 2, 3, or any number.

But for others, if you are assigning or you are not assigning, that means you are assigning a null value. So, null and 0 are some other concepts, but that means you are seeing present, absent, or different variations of presence, and so that means you are assigning a value. When data values are not available for a particular cell, they are described as no data cells. So, if there is no data for a cell, it is described as null. So now let us see the operations, particularly map algebra and the grid operations.

Map algebra is a core concept in raster analysis involving mathematical operations. It is useful to manipulate raster data through these four representations of basic grid operations. Let us see the local, focal, zonal, and global. These are the four basic grid operations as far as the mathematical algebra or map algebra is concerned. So, the local function works on every single cell, whereas the focal function processes the data of each cell based on the information of a specific neighborhood.

So, the focal function is focused on the neighborhood criteria, and the zonal function works on each group of cells of identical values. So that means a group of cells because we are talking about the zonal. And if we are talking about the global function, it works on a cell based on the data of the entire grid. So, as far as the map algebra and the mathematical operations are concerned, these four basic grid operations are there: local, focal, zonal, and global functions. Now, let us talk about the data collection and input, and the data storage and management.

The image shows a presentation slide with a blue and white background. The slide is divided into two main sections. The first section is titled "Data Collection and Input" and lists three bullet points: "GPS (Global Positioning Systems): Accurate Data Collection for Geographic Locations", "REMOTE SENSING: Satellite Imagery and Aerial Photography for Large-Scale Spatial Data", and "FIELD SURVEYS AND OBSERVATIONS: Ground-Based Data Collection for Higher Accuracy". The second section is titled "Data Storage and Management" and lists three bullet points: "GIS Stores Both Spatial and Attribute Data", "Data Management Tools Ensure Data Quality, Consistency, and Accessibility", and "GIS Databases, Often Spatially Enabled, Allow for Efficient Storage and Retrieval". In the bottom right corner, there is a small inset video of a man in a suit speaking. The slide also features logos for NPTEL and other institutions at the bottom left.

So, we know about remote sensing. So, different forms of remote sensing. So, essentially what they give, they produce data, data in a spatial framework X, Y, and/or the Z frame. So, satellite imagery, including satellite imagery and images coming from other platforms like aerial photography or UAVs. Provide, or even from ground-based things, provide large-scale spatial data.

So, it is a source of spatial data. Remote sensing, as far as GIS is concerned, provides large-scale spatial data. Now, as far as GNSS is concerned, it gives us the local geographical locations also in terms of X, Y, and Z. So, GNSS is another source of data as far as input or data collection is concerned. And then, we also get a lot of data from field surveys and observations. So, ground-based data collection also serves as a source of input data to the GIS framework. Now, once this is available or once this is done, we

talk about data storage and management, which involves both storage of spatial and attribute or non-spatial data.

The data management tools ensure data quality, consistency, and accessibility. So, we have a lot of database management, DBMS, or relational database management, RDBMS, these kinds of packages where we talk about the relation between the data, and there, we also talk about the quality of the data, the consistency of the data, and the accessibility of data. So, this all falls under the framework of data management tools. So, GIS databases, often spatially enabled, allow for efficient storage and retrieval of data. So, in essence, GIS involves, apart from query and capture, it involves the storage and retrieval of data, and the data should be of good quality, maintaining consistency, and the accessibility factor is also dealt with.

Now, with respect to spatial analysis, visualization, and mapping, friends, as far as spatial analysis is concerned, we can categorize them into these four: proximity, overlay, networking, and spatial interpolation. As far as proximity analysis is concerned, it evaluates the distance and spatial relationship between two features. Whereas, in the case of overlay, it combines more than one. So, multiple layers are used to analyze interactions between different datasets. But, in the case of network analysis, it examines and optimizes networks such as transport and utility sectors.

The slide is titled "Spatial Analysis" and "Visualization and Mapping". It contains the following text:

- Spatial Analysis**
- Proximity Analysis: Evaluates the Distance and Spatial Relationship between Features
- Overlay Analysis: Combines Multiple Layers to Analyze Interactions between Different Datasets
- Network Analysis: Examines and Optimizes Networks, such as Transportation and Utility Systems
- Spatial Interpolation: Uses known data points to estimate unknown values across a landscape

**Visualization and Mapping**

GIS creates Detailed Maps and Visualizations, using various Symbology, Colors, and Labels to represent Data

Visualizations are Crucial for Interpreting Complex Data and Conveying Insights

The slide also features the NPTEL logo in the bottom left corner and a small inset image of a man in a suit in the bottom right corner.

So, in transport, one line is on this side, and one line is on that side. So, things are arranged in the form of a network. So, in network analysis, we talk about optimizing networks in the form of utility sectors or transport sectors, things like that. Then, as far as the fourth one, spatial interpolation is concerned, it uses known data points to estimate unknown values across a landscape. So, this is very important because, many times in analysis, you may not have all the information at hand.

So, that means, with a set of information at hand, based on certain principles, statistics, and logic, we predict, come out with, or generate a new set of data. So, it uses known data points to estimate unknown values across a landscape. Now, once that is done, let us talk about visualization and mapping efforts. The GIS creates detailed maps and visualizations using various symbology, colors, and labels to represent data. So, this is another aspect or a powerful aspect.

It helps us in visualizing the data effectively. So, the visualization tools, using different visualization techniques, the detailed maps, and the outputs are visualized and demonstrated using different symbology in terms of color variations and labels that represent different data sets. So, visualizations are crucial for interpreting complex data and conveying various insights about the analysis or about that particular application, including applications in the mining industry or mining sector. So, GIS applications in mine planning and environmental management can be arranged into these four broad segments. One is exploration, operations, logistics, and environmental health and safety.



In terms of exploration, it is useful for prospecting and land use planning. GIS also helps in mobile work and data collection. Mapping and analysis, data management, and collaboration. As far as operations are concerned, it could be useful in planning blast holes, haul road conditions, heap leaching process monitoring, tailings, storage facility, and management. As far as logistics in the mining sector are concerned, it could be useful in stockpile and inventory management.

Real-time fleet tracking and route optimization, where we can use a lot of networking approaches. Supply chain management could involve the networking of other operations, including risk management, and it also has the power to analyze the market situation. So, market analysis is also very well done these days using GIS tools and GIS technologies.

And in the environmental health and safety sector, yes, environmental monitoring, inspection, and mine reclamation, GIS has its own role to play. So, what I mean to say is that GIS is about the capture of different data, both spatial and non-spatial.

It and analyzing it based on our condition, it has tremendous application. It is a rich tool with diverse applications, so we must understand the power of GIS as a tool in mining industries. So, there are a lot of studies. We thought to pick this study published this year in 2024 by Shome et al. that talks about the assessment of environmental severity around the mining region using a GIS-based AHP analytical hierarchical process model. So, this case study has been, and this study has been done on the site at Dongri, Bhujrang, Manganese ore mine in India. So, this identifies high-risk zones to guide the targeted environmental management planning, and it has also used an AHP-based method for prioritization.

**Case Study: Assessment of Environmental Severity Around the Mining Region Using GIS-Based AHP Model: A Case Study of the Dongri Buzurg Manganese Ore Mine, India**

Identify High-Risk Zones to guide Targeted Environmental Management and Planning, using a GIS-based Analytic Hierarchy Process (AHP)

- **Satellite imagery** - Resourcesat-2 LISS-III, Landsat-8 OLI and SRTM-1
- **AHP is used to Rank Environmental Factors** by comparing them based on their Severity Impact
- **Weights are assigned to Factors**, and the GIS Platform integrates these weights to create an Environmental Severity Map

Environmental Parameters Analyzed			
Air Quality	Water Quality	Noise Pollution	Soil Quality
Land Use and Land Cover	Vegetation Health	Rainfall and Topography	Distance from Mine

**Result: Environmental Severity Index (ESI) Map**  
Low Risk (29%), Moderate Risk (37%), High Risk (22%), Very High Risk (12%)

The study provides a GIS-AHP-based approach to assess environmental severity in mining regions. This methodology can be applied to other mining sites to enhance environmental management and conservation efforts.

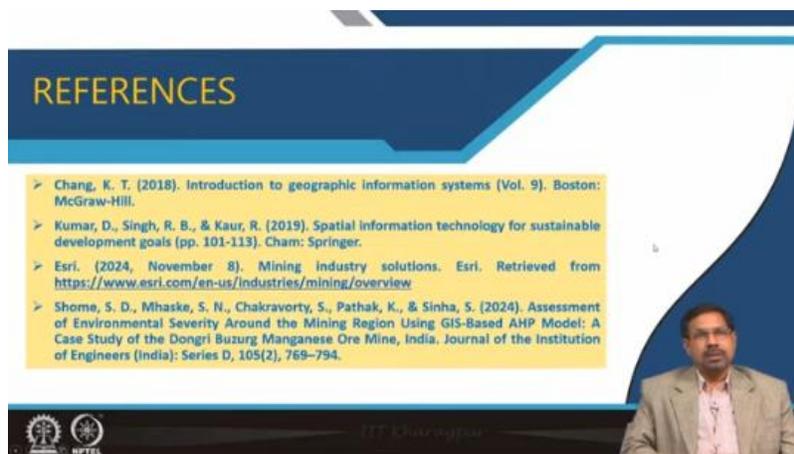
(Shome et al., 2024)

And let us see the satellite data Shome et al. have used: the Indian remote sensing data IRS 2, LISS 3, which is 23.5-meter resolution, Landsat OLI, and the SRTM data. So, SRTM means you are using an elevation map or elevation data. The AHP was used to assign ranks for different environmental factors by comparing them based on their severity impact. And in following this AHP process, the weights were assigned to factors, and the GIS platform integrates these weights. To create an environmental severity map.

So, environmental parameters are analyzed, such as water quality, air quality, noise pollution, soil quality, land use, land cover, vegetation health, rainfall, and topography. And also, the distance from mining using the buffer operation. So, whatever is needed, we can do the analysis because they are all, as far as they are concerned, different data only. So, it is left to us as interpreters or as analysts what we need to do. So, in this study,

the result is finally a map which is showing different environmental severity levels in terms of an index.

So that could be arranged in terms of a quantitative or qualitative kind of thing, from low to high. So this study, which we picked as a case study, is a GIS-based AHP approach to assess the environmental severity in mining regions. So this methodology can be applied to other mining sites to enhance environmental management and conservation efforts. So GIS is a powerful tool for many applications in the mining sector. So, these are the four references we have used to discuss this particular introductory class on geographic information systems.



So, at the end, what we take home, the take-home messages are: GIS is essential for environmental management, especially in high-impact fields like the mining sector. GIS integrates both spatial and non-spatial data for in-depth analysis as far as patterns, risks, and efficiency are concerned. GIS-based AHP processes or AHP approaches help in assessing environmental severity in mining areas. Identifying high-risk zones is also useful, thereby guiding targeted mitigation strategies which are required by planners. GIS also supports effective decision-making and sustainable practices.

## CONCLUSION

- GIS is Essential for Environmental Management, especially in High-Impact Fields like Mining
- Integrates Spatial and Non-Spatial Data for In-Depth Analysis of Geographic Patterns, Risks, and Efficiencies
- GIS-based AHP Approach helps assess Environmental Severity in Mining Areas
- Identifies High-Risk Zones and Guides Targeted Mitigation Strategies
- Supports effective Decision-Making and Sustainable Practices
- Provides a Replicable Framework for Resource Management and Conservation
- Promotes Reduced Environmental Impact across Mining Sites

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It provides a replicable framework for resource management and conservation. Look at the term replicable framework. This particular methodology can be repeated in other sites with other datasets. It can be replayed with many other datasets and can be replicated. So, this replication is a very important, or repeatability is a very important property as far as GIS analysis is concerned.

So, in essence, GIS promotes reduced environmental impact across mining sites by analyzing and integrating the data that is useful in the mining sector or mining industries. In future classes, we will be talking more about GIS applications and their utilities in the mining sector. Thank you very much.