Chapter 7: Cartography and Thematic Mapping

Introduction

Cartography is the science and art of map-making. It forms the backbone of spatial analysis, visualization, and geo-informatics. With the advent of Geographic Information Systems (GIS) and remote sensing technologies, cartography has evolved from traditional hand-drawn maps to sophisticated digital maps that can be dynamically updated and customized for various applications. Thematic mapping, a subfield of cartography, focuses on representing spatial patterns of specific themes such as population density, land use, soil types, and more. This chapter explores the principles of cartography, types of maps, thematic mapping techniques, and their applications in civil engineering and geo-spatial decision-making.

7.1 Basics of Cartography

7.1.1 Definition and Scope

- **Cartography** is the discipline dealing with the conception, production, dissemination, and study of maps.
- Encompasses both **topographic** and **thematic maps**.
- Involves understanding **scale, projections, symbology, generalization, and aesthetics**.

7.1.2 Components of a Map

Every map includes certain standard components:

- **Title**: Indicates the subject of the map.
- **Legend**: Explains the meaning of symbols and colors.
- **Scale**: Expressed as representative fraction (e.g., 1:50,000).
- **North Arrow**: Shows orientation.
- **Grid or Graticule**: Latitude-longitude or UTM grid for spatial reference.
- **Source and Date**: Indicates data origin and relevance.

7.1.3 Map Scales

- **Large Scale Maps** (e.g., 1:10,000): More detail, smaller area.
- **Medium Scale Maps** (e.g., 1:50,000): Balanced detail and coverage.
- **Small Scale Maps** (e.g., 1:250,000): Less detail, broader area.

7.1.4 Map Projections

A map projection is a mathematical transformation of Earth's 3D surface onto a 2D map. Types include:

- **Conformal** (preserves angles): e.g., Mercator.
- **Equal Area** (preserves area): e.g., Mollweide.
- **Equidistant** (preserves distance): e.g., Azimuthal Equidistant.
- **Compromise** (minimizes distortion): e.g., Robinson.

7.1.5 Symbolization

- Use of **points, lines, and polygons** to represent features.
- Symbol properties:
  - **Size**: Quantity or magnitude.
  - **Shape**: Type of feature.
  - **Color**: Thematic differentiation or intensity.
  - **Pattern**: Texture representation (e.g., forest, water).

7.2 Principles of Thematic Mapping

7.2.1 Thematic vs. Topographic Maps

- **Topographic maps** show physical and man-made features.
- **Thematic maps** highlight specific themes, such as land use, rainfall, or socio-economic patterns.

7.2.2 Characteristics of Thematic Maps

- Focuses on a single topic or variable.
- Designed for **analytical and decision-making purposes**.
- Requires **data classification and symbolization**.

7.2.3 Thematic Map Design Process

1. **Data Acquisition**: From surveys, remote sensing, census, etc.
2. **Data Classification**:
   - **Equal Interval**
   - **Quantile**
   - **Natural Breaks (Jenks)**
   - **Standard Deviation**
3. **Symbol Selection**: Appropriate to data type.
4. **Map Layout Design**: Balancing visual clarity and information density.

5. **Cartographic Generalization**: Simplifying details while retaining key information.

7.3 Types of Thematic Maps

7.3.1 Choropleth Maps

- Represent statistical data using **shaded or colored regions**.
- Suitable for normalized data (e.g., population density).
- Pitfalls: Misleading if not normalized.

7.3.2 Dot Density Maps

- Use **dots** to represent a fixed quantity.
- Useful for visualizing **spatial distribution** of phenomena like population.

7.3.3 Proportional Symbol Maps

- Symbols (usually circles) scaled in proportion to data values.
- Effective for comparing **quantitative values** between locations.

7.3.4 Isoline Maps

- Show continuous data (e.g., elevation, temperature) with **lines of equal value**.
- Include contour maps, isobars, isotherms.

7.3.5 Cartograms

- Distort geographic space to represent a variable (e.g., resizing states based on population).
- Useful for **emphasis** in thematic storytelling.

7.3.6 Flow Maps

- Represent movement of goods, people, or data using **arrows**.
- Width and direction indicate quantity and direction.

7.3.7 Heat Maps (Density Maps)

- Represent **intensity of occurrences** with color gradients.
- Commonly used in crime mapping, traffic accidents, and retail planning.

7.4 Digital Cartography and GIS Integration

7.4.1 GIS-based Mapping Tools

- Software: **ArcGIS, QGIS, GRASS GIS, ERDAS Imagine**.
- Capabilities:
  - Layer-based thematic visualization
  - Dynamic symbology
  - Spatial querying and analysis
  - Automated layout generation

7.4.2 Map Servers and Web Mapping

- Web-based platforms: **Google Maps, OpenStreetMap, Mapbox, Leaflet**.
- Features:
  - Interactive user experience
  - Real-time data integration
  - Thematic overlays on base maps

7.4.3 Standards and Interoperability

- Use of **OGC (Open Geospatial Consortium)** standards like:
  - **WMS**: Web Map Service
  - **WFS**: Web Feature Service
  - **KML**, **GeoJSON** formats

7.5 Cartographic Design and Visualization Best Practices

7.5.1 Visual Hierarchy

- Emphasize important features using color, contrast, and size.
- Use of **grids, white space, and balanced composition**.

7.5.2 Color Theory in Mapping

- **Sequential palettes**: For ordered data (e.g., rainfall).
- **Diverging palettes**: For emphasizing deviations (e.g., temperature anomalies).
- **Qualitative palettes**: For categorical data (e.g., land cover).

7.5.3 Typography and Labeling

- Legible fonts and sizes.

- Hierarchical labeling for clarity.
- Avoid clutter by using **dynamic labeling and leader lines**.

7.5.4 Ethical Cartography

- Avoid data manipulation or misleading representation.
- Represent uncertainty where applicable.
- Maintain **source transparency** and **data accuracy**.

7.6 Applications in Civil Engineering

- **Urban Planning**: Land-use patterns, zoning analysis.
- **Transportation Engineering**: Traffic flow maps, accessibility analysis.
- **Water Resources**: Watershed maps, rainfall and runoff distribution.
- **Environmental Engineering**: Pollution heat maps, green cover mapping.
- **Disaster Management**: Hazard zone mapping, evacuation route planning.

7.7 Challenges and Future Trends in Thematic Cartography

7.7.1 Challenges

- Data quality and resolution
- Symbol overload and cognitive load
- Real-time data visualization
- Cultural interpretation of map symbols

7.7.2 Future Trends

- **3D and Augmented Reality Mapping**
- **AI-Assisted Cartography** for automated symbolization and data classification
- **Real-Time Thematic Mapping** using IoT and live sensors
- **Crowdsourced Cartography** via mobile apps

7.8 Advanced Techniques in Thematic Cartography

7.8.1 Dynamic and Animated Maps

- **Dynamic Maps** update data in real-time, commonly used in monitoring traffic, air quality, and disaster situations.
- **Animated Maps** depict changes over time (e.g., urban sprawl from 1990 to 2025).

- Tools: **Tableau, TimeSlider in QGIS, ArcGIS Dashboards**.

7.8.2 Multivariate Mapping

- Combines two or more datasets in a single map.
- Example: Showing rainfall patterns (color gradient) and crop yield (proportional symbols) together.
- Complex but powerful for **multi-criteria decision analysis (MCDA)** in civil projects.

7.8.3 3D and Virtual Cartography

- Use of **Digital Elevation Models (DEMs)** and **LiDAR data** for terrain visualization.
- 3D maps are essential in:
  - **Infrastructure planning** in hilly terrain
  - **Flood simulation models**
  - **Slope analysis for road alignment**
- Software: **ArcScene, QGIS 3D View, BlenderGIS, Google Earth Pro**

7.8.4 Cartographic Automation

- Use of **Python scripting (e.g., with ArcPy)** and **ModelBuilder** for batch map creation.
- Automates:
  - Map generation
  - Symbology application
  - Exporting and publishing

7.9 Use of Remote Sensing in Thematic Mapping

7.9.1 Role of Satellite Data

- Remote sensing imagery from satellites like **Landsat, Sentinel-2, IRS**, etc., provide base layers and thematic data.
- Applications:
  - **Land cover classification**
  - **Vegetation health index (NDVI maps)**
  - **Urban heat island mapping**
  - **Soil moisture distribution**

7.9.2 Image Classification for Mapping

- **Supervised Classification**: Analyst provides training samples (e.g., for land use).
- **Unsupervised Classification**: Algorithm groups pixels based on spectral similarity.
- Output used to produce thematic raster maps.

7.10 Case Studies in Civil Engineering

7.10.1 Urban Flood Risk Zoning – Chennai, India

- Data layers: DEM, rainfall intensity, land use, drainage network.
- Tools used: ArcGIS, HEC-RAS, QGIS.
- Map output: Flood hazard zones (low to high risk).
- Application: Stormwater drain redesign and evacuation planning.

7.10.2 Road Network Thematic Map – Shillong Hill Roads

- Inputs: Slope map, soil type, rainfall erosivity, land use.
- Output: Map of areas suitable for highway expansion.
- Importance: Reduced cost and risk in road planning.

7.10.3 Groundwater Potential Mapping – Punjab

- Factors mapped: Lineament density, geology, slope, land use.
- Weighted overlay analysis in GIS.
- Helped in **siting tube wells** and **regulating water use**.

7.11 Cartographic Standards and Metadata

7.11.1 National and International Standards

- **BIS (Bureau of Indian Standards)** provides map layout, scale, and symbology norms.
- **ISO 19115**: Metadata standard for geographic data.
- **FGDC (Federal Geographic Data Committee, USA)**: Metadata for spatial datasets.

7.11.2 Metadata in Thematic Mapping

- Metadata describes:
  - **Source of data**
  - **Date of data collection**
  - **Coordinate system**

  - **Data quality/accuracy**

- Essential for **map credibility**, especially in public or academic platforms.

7.12 Ethical and Legal Issues in Cartography

7.12.1 Data Privacy

- Thematic maps involving demographic or health data must respect individual privacy.
- Aggregation and anonymization are recommended.

7.12.2 Intellectual Property and Copyright

- Use of third-party base maps or data must follow licensing norms (e.g., Creative Commons, ODbL).
- Attribution is required for open-source datasets like **OpenStreetMap**.

7.12.3 Misrepresentation and Bias

- Deliberate distortion or selective mapping can manipulate public perception.
- Ethical mapping demands **neutral symbolization**, **transparent sources**, and **clear legends**.

7.13 Practical Exercises and Field Applications (Lab Integration)

7.13.1 Thematic Map Preparation Using QGIS

- Import base map and attribute data (e.g., village-wise literacy rate).
- Choose appropriate classification method (e.g., Quantiles).
- Apply color gradient symbology.
- Export to PDF with legend, scale, and metadata.

7.13.2 Mapping Land Use Change from Satellite Imagery

- Acquire Sentinel-2 images for two time periods.
- Perform classification using Semi-Automatic Classification Plugin (QGIS).
- Generate land use change map and analyze trends.

7.13.3 Interactive Web Map Creation

- Use **Leaflet.js** or **Mapbox GL JS**.
- Embed thematic layers (e.g., population density, land degradation).

- Publish for mobile/desktop accessibility.
