expanded its usage. Today, GIS is an integral tool in various sectors, including transportation, logistics, agriculture, and public safety, providing critical insights and aiding in decision-making processes.

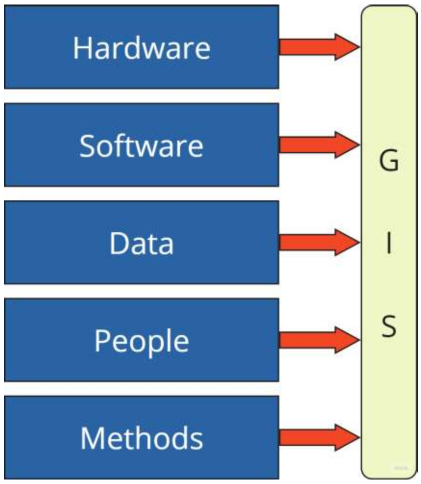

Figure 8.1 Components of GIS

Source: Author, adapted from Kishore and Rautray (n.d.).

Figure 8.1 shows the five essential components of a Geographic Information System (GIS), according to Kishore and Rautray (n.d.):

- **Hardware:** The physical devices used to run GIS software and store data, such as computers, servers, GPS devices, and other peripherals.
- **Software:** The programs and applications that perform GIS functions, enabling users to analyze and visualize spatial data.
- **Data:** The spatial and non-spatial information that GIS systems analyze, including maps, satellite imagery, and tabular data.
- **Methods:** The techniques and procedures used to analyze GIS data, such as algorithms and statistical models.
- **People:** The professionals and users who operate and manage GIS technology, from data analysts to decision-makers.

Geographic information systems have a wide range of applications across various industries, making them indispensable tools for spatial data analysis and decision-making. In business intelligence, GIS is utilized for market analysis, site selection, and logistics optimization, helping companies to make data-driven decisions based on geographic trends (Longley et al., 2015). Environmental management leverages GIS for natural resource management, environmental monitoring, and disaster response, enabling more effective conservation efforts and emergency planning (Goodchild et al., 2018). By integrating and analyzing spatial data, GIS improves decision-making processes through precise geographic insights and visualizations, enabling organizations to identify patterns and relationships that are not immediately apparent in traditional data formats (Longley et al., 2015).

One of the core components of GIS technology is the concept of layers. According to Esri (n.d.c), a layer is a slice of the geographic reality in a particular area. Each layer in a GIS corresponds to a specific type of data, such as roads, land use, elevation, water bodies, or population density. Figure 8.2 shows the example of different kinds of data on one map (streets, buildings and vegetation), each corresponding to one layer.

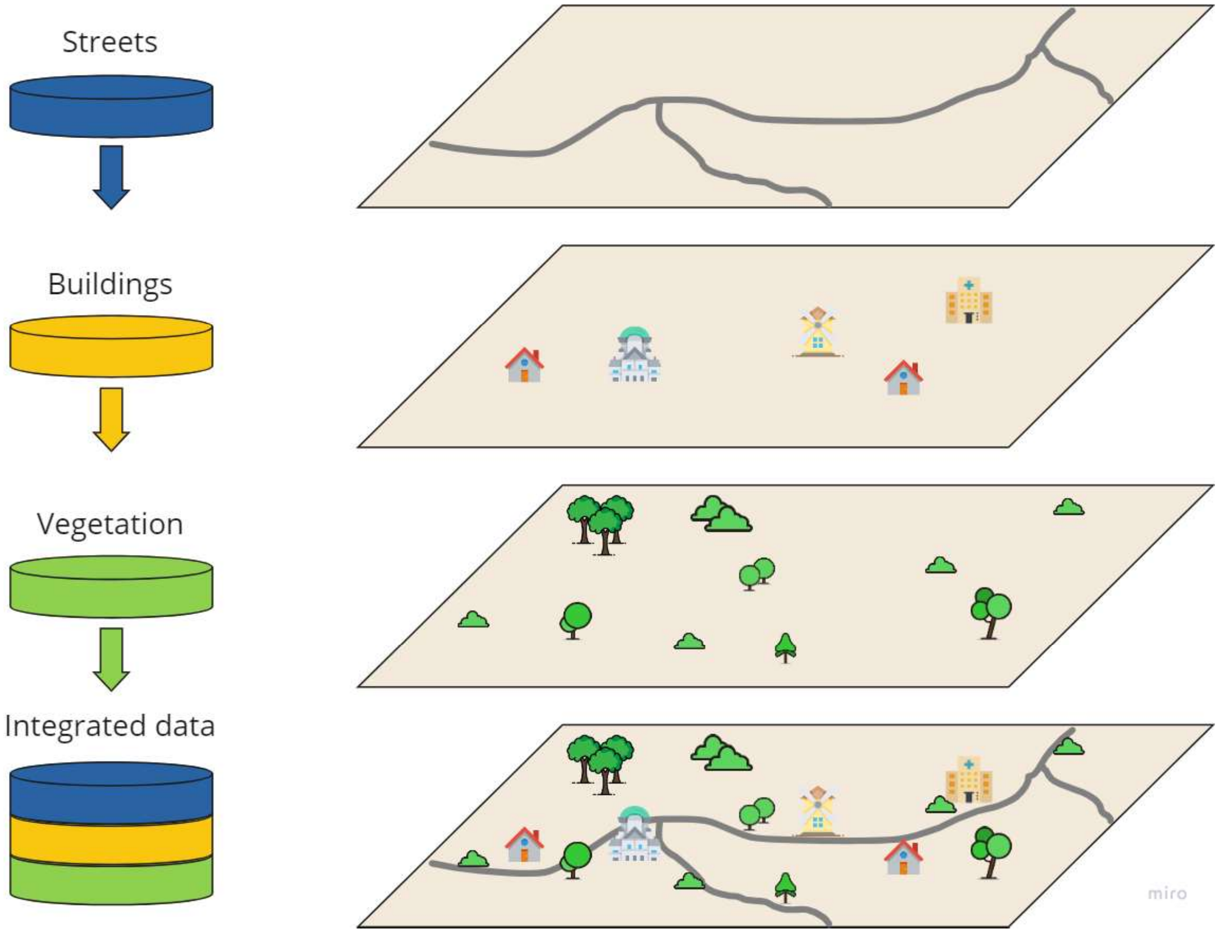

Figure 8.2 GIS layers

Source: Author, adapted from National Geographic (n.d.).

Geographic information systems rely on a variety of data types to represent, analyze, and visualize geographical information. GIS data can be broadly categorized into two main types: raster and vector data.

According to Dempsey (2024), the predominant form of GIS data is **vector data**. Points, lines and polygons used to represent geographic data are examples of vector data. In a vector representation, all lines are captured as points connected by precisely straight lines (Longley et al., 2015). Point data represent discrete data points or specific locations, like schools, city names or points of interest. Line data represent linear features like roads and rivers and polygons are used for area features such as lakes, administrative boundaries, and forests (Dempsey, 2024).

Raster data is a grid-based data structure composed of pixels or cells, each with an associated attribute. The most common sources of raster data are satellite imagery, aerial imagery, remotely sensed data, and data with shaded relief and topography (Dempsey, 2024; Longley et al., 2015).

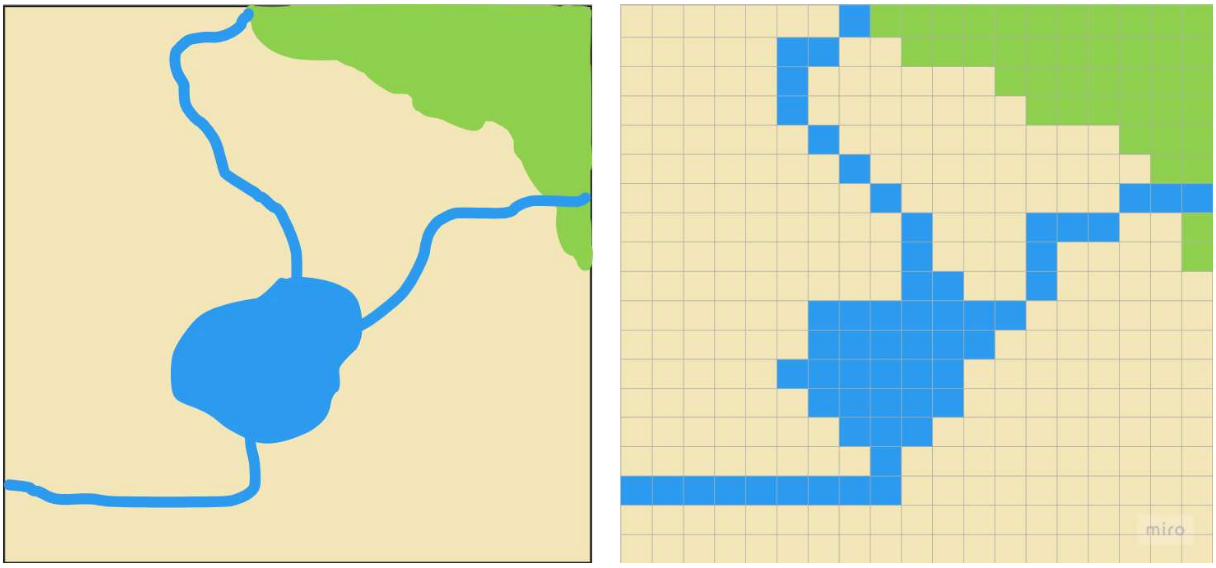

Figure 8.3 Vector (left) and raster (right) data

Source: Author.

Figure 8.3 shows two map representations using vector (on the left) and raster (on the right) data. Vector data include polygons (lake and forest) and lines (rivers), and raster data include a grid where each cell represents one color (blue, yellow or green).

It is important to understand the different kinds of GIS data in order to use them effectively in business intelligence. Vector data is ideal for precise mapping and analysis of discrete geographical features, while raster data is great for representing continuous data and large-scale environmental data.

8.2. GIS in logistics

Geographic Information Systems (GIS) have fundamentally transformed the logistics sector, providing tools that enable more efficient, cost-effective, and strategic decision-making processes. The integration of GIS in logistics allows the visualization, analysis, and interpretation of spatial data, which is crucial for optimizing routes, managing supply chains, and enhancing overall operational efficiency.

To address logistical challenges, GIS technology combines state-of-the-art data management and analytical techniques with the science of geography. Logistics professionals can see patterns, relationships, and trends that are not visible in traditional data formats by using it to make it easier to overlay different data sets on a map. According to Esri (2017), strategic planning and operational optimization benefit greatly from this spatial perspective.

One of the primary applications of GIS in logistics is route optimization. By analyzing spatial data, logistics companies can determine the most efficient routes for delivery, reducing travel time, fuel consumption, and overall operational costs. For instance, GIS can account for traffic patterns, road conditions, speed limits to optimize routing in real time (Ramzan, 2023). This capability not only improves efficiency but also enhances customer satisfaction by ensuring timely deliveries.

Sureshkumar et al. (2017) conducted a study that highlights the numerous advantages of GIS and emphasizes its transformative potential in route optimization for traffic management. GIS enables real-time data application for dynamic traffic adjustments and comprehensive spatial analysis by facilitating the integration of various data types, including GPS and satellite imagery. Because of this integration, there are major time and cost savings due to shorter travel distances and less fuel used. Decision-making processes are improved by the spatial visualization capabilities of GIS, which reveal patterns and trends that are hidden in conventional data formats. All things considered, the study shows that GIS-based route optimization not only lowers environmental impact and increases operational efficiency, but it also offers a strong framework for dealing with intricate urban traffic issues.

The application of Geographic Information Systems (GIS) in optimizing municipal solid waste (MSW) collection routes has proven to be highly effective in enhancing operational efficiency and reducing costs. Singh and Behera (2018) demonstrated that the integration of GIS and the network analyst tool in ArcGIS significantly reduced haul distances by an average of

27.78%, highlighting substantial improvements in waste management logistics in Kanpur, India. Similarly, Nguyen-Trong et al. (2016) utilized a combined approach of GIS, equation-based optimization, and agent-based modeling to dynamically optimize waste collection routes in Hagiang City, Vietnam, achieving a cost reduction of 11.3%. These studies underscore the transformative potential of GIS in addressing the complexities of urban waste management, particularly through the integration of real-time data and advanced modeling techniques. By leveraging GIS for spatial analysis and route optimization, municipalities can achieve more sustainable and efficient waste management practices, thereby enhancing overall service delivery and reducing environmental impact.

Hemidat et al. (2017) conducted a study which aims to improve the efficiency of municipal solid waste (MSW) collection in the several Jordan cities by using GIS techniques. The researchers developed optimized waste collection scenarios using the ArcGIS Network Analyst tool, aiming to reduce operational costs, vehicle operating times, and environmental impacts. The optimized scenarios showed notable savings compared to the current state (S0). Specifically, Scenario S1 resulted in cost savings of 15%, 6%, and 11% for Irbid, Karak, and Mafraq, respectively. Scenario S2 demonstrated cost savings of 13%, 3%, and 6% for the same cities. The combined scenario (S3) yielded the highest savings, with 23%, 8%, and 13% reductions in total costs. These findings highlight the substantial impact of GIS-based route optimization on reducing operational costs, vehicle operating times, and environmental impacts by minimizing fuel consumption and emissions.

GIS-based analytics significantly enhance blood supply chain management by providing real-time visibility and facilitating better decision-making. The integration of GIS with data mining and other analytic techniques allows for efficient tracking, management, and optimization of blood resources, leading to improved operational efficiency and reduced wastage (Delen et al., 2011).

Also, GIS plays a vital role in urban infrastructure planning and management by providing a robust platform for integrating and analyzing spatial data. The use of GIS in this context enables more informed decision-making, leading to optimized infrastructure investments and enhanced service delivery. The study conducted by Irizarry et al. (2013) highlights the effectiveness of GIS in managing urban infrastructure and improving operational efficiencies.

The use of GIS in route optimization across different domains, such as municipal solid waste management, blood supply chain management, and urban infrastructure planning, has demonstrated substantial benefits. GIS enhances operational efficiency by integrating spatial data with advanced analytical tools, facilitating real-time decision-making and optimizing resource utilization. Studies have shown significant cost reductions and improved service delivery through GIS-based route optimization, underscoring its critical role in managing complex logistical operations. By leveraging GIS technology, organizations can achieve sustainable practices, reduce environmental impacts, and enhance overall operational effectiveness.

8.3. Future trends in GIS

Geographic information systems are undergoing significant transformations driven by technological advancements and increasing demands for spatial data analysis. This sub-chapter will explore the future trends in GIS, focusing on emerging technologies, cloud computing, the integration of big data and the role of artificial intelligence (AI) and machine learning (ML).

The future of GIS is shaped by several key trends and innovations that are transforming how we collect, analyze, and utilize spatial data. A significant trend is the integration of advanced technologies such as cloud computing, AI, machine learning (ML), and drone-based data collection. These technologies enhance the efficiency and capabilities of GIS, allowing for real-time data processing and more sophisticated spatial analyses. **Cloud computing** is revolutionizing GIS by providing scalable and accessible platforms for storing and processing large datasets. This shift enables organizations to leverage vast amounts of geospatial data without the need for significant on-premises infrastructure. The adoption of GIS as a service is growing, allowing users to access powerful GIS tools and data analysis capabilities through cloud platforms. This trend is making GIS more accessible and cost-effective, particularly for smaller organizations and industries with limited resources. **AI and ML** are playing important roles in automating and enhancing spatial data analysis. These technologies can identify patterns, make predictions, and provide insights from complex datasets that would be challenging to analyze manually. For instance, AI algorithms can process satellite imagery to detect changes in land use, while ML models can predict traffic patterns based on historical data. The integration of AI and ML with GIS is enabling more accurate and timely decision-making across various sectors, from urban planning to disaster management. The advancements in **drone technology** are also significant trends in GIS. Drones equipped with high-resolution cameras and sensors are increasingly used for data collection in hard-to-reach areas. These tools provide real-time, high-accuracy data that can be integrated into GIS for detailed mapping and analysis. This trend is particularly beneficial for environmental monitoring, infrastructure inspection, and agricultural management. Another emerging trend is the use of **augmented reality** (AR) and **virtual reality** (VR) in GIS. These technologies offer new ways to visualize and interact with spatial data, providing immersive experiences that can enhance understanding and decision-making. For example, AR can overlay geospatial data onto real-world views, helping users visualize underground utilities or navigate complex environments. VR can create detailed simulations of urban landscapes, allowing planners to explore different scenarios and their potential impacts. **Real-time data analysis** is becoming increasingly important in GIS applications. The ability to process and analyze data as it is collected enables more responsive and dynamic decision-making. This capability is enhanced by the integration of GIS with the Internet of Things (IoT), where data from connected devices can be continuously monitored and analyzed. Real-time GIS is being used in applications such as traffic management, emergency response, and environmental monitoring, where timely information is critical. The expansion of GIS applications into new industries and sectors is also noteworthy. GIS is now being used in fields such as healthcare, where it helps track disease outbreaks and optimize healthcare delivery. In retail, GIS analyzes customer demographics and optimizes store locations. Technology is also crucial in smart city initiatives, providing the spatial intelligence needed to manage urban infrastructure and resources efficiently (Kerski, 2022; MGISS, 2023).

As can be seen, the integration of GIS in logistics has revolutionized the industry by enhancing operational efficiency, reducing costs, and improving customer satisfaction. As GIS technology continues to evolve, its applications in logistics will expand, offering even more sophisticated tools for addressing complex challenges. By leveraging these advancements, logistics companies can maintain a competitive edge and adapt to the dynamic demands of the global market.

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