GIS: A Historical Perspective and Key Components

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ABSTRACT:

Urbanization is influenced by geographical, social, economic and political industrial factors. Urbanization is considered as one factor in development. Urbanization has some negative benefits as well as Geographic Information Systems (GIS) represent a transformative technology that integrates hardware, software, spatial data, analytical methods, and human expertise to capture, store, manipulate, analyze, manage, and visualize geographically referenced information. This work provides a historical overview of GIS development, tracing its conceptual roots from early spatial analysis efforts—such as John Snow's pioneering cholera map in 1854—to the formal birth of modern GIS in the 1960s with Roger Tomlinson's Canada Geographic Information System (CGIS), widely regarded as the world's first operational GIS. Key milestones include advancements in computer cartography during the 1960s–1970s, the commercialization of GIS software in the 1980s (led by organizations like ESRI), and the subsequent proliferation driven by personal computing, the internet, and open-source tools. The paper also examines the five essential components of GIS—hardware, software, data (including spatial and attribute components), people, and methods (procedures/workflows)—highlighting how their integration enables powerful geospatial decision-making across diverse fields such as environmental management, urban planning, public health, disaster response, and business intelligence. By reflecting on GIS's evolution from analog mapping precursors to today's cloud-based, AI-enhanced platforms, this discussion underscores its enduring role as a cornerstone of spatial thinking and data-driven problem-solving in the modern world.

KEY WORDS: GIS, Components, Methods, Data, Software, Hardware, Peoples/ live ware.

INTRODUCTION:

The ability to understand and represent the spatial relationships between phenomena has been fundamental to human progress for centuries. From ancient cartographic representations used for navigation and territorial claims to sophisticated digital systems today, geography has always served as a framework for organizing knowledge about the world. The advent of Geographic Information Systems (GIS) marked a revolutionary shift by

combining traditional mapping principles with computational power, enabling not only the visualization of spatial data but also its dynamic analysis, modeling, and prediction. GIS emerged as a distinct discipline in the mid-20th century, driven by the convergence of advancements in computer technology, quantitative geography, and the growing need for efficient management of large-scale natural resource and land-use inventories. Often credited to Canadian geographer Roger Tomlinson, who coined the term "Geographic Information System" in the 1960s while developing the Canada Geographic Information System (CGIS) for automated land inventory, GIS has since evolved dramatically. Early precursors, such as John Snow's 1854 cholera map that linked disease cases to a contaminated water pump through spatial pattern recognition, demonstrated the analytical power of linking "what" (attributes) with "where" (location)—a core principle that remains central to GIS today. Over the decades, GIS has transitioned from mainframe-based systems accessible only to governments and large institutions to ubiquitous tools embedded in smartphones, web platforms, and decision-support systems worldwide. This evolution has been shaped by key technological milestones, including the development of computer mapping software in the 1960s (e.g., SYMAP at Harvard Laboratory), the commercialization of GIS in the 1980s, the rise of desktop and web GIS in the 1990s–2000s, and recent integrations with remote sensing, GPS, big data, artificial intelligence, and cloud computing. At its foundation, any functional GIS relies on five interdependent components: hardware (computers, sensors, GPS devices), software (tools for data input, management, analysis, and visualization), data (both spatial geometries and associated attributes), people (users, analysts, decision-makers), and methods (procedural workflows and analytical techniques). Understanding these elements, alongside the historical context of their development, provides essential insight into how GIS has become indispensable across disciplines ranging from environmental science and urban planning to epidemiology, transportation, agriculture, and emergency management.

HISTORICAL DEVELOPMENT OF GIS:

The GIS history dates back 1960 where computer based GIS have been used and manual procedures were in life 100 years earlier or so. The initial developments originated forth America with the organizations such as US Bureau of the Census, The US Geological survey and The Harvard Laboratory for computer graphics and Environmental Systems Research institute (commercial). Canadian Geographic Information Systems (CGIS) in Canada, Natural experimental Research Center (NREC), and Department of Environment (DOE) notable organization in U.K. involved in early developments. The laboratory for Computer Graphics and spatial Analysis of the Harvard Graduate School of Design or the State

University of New York at Buffalo achieved worldwide recognition**.** Commercial agencies started to develop and offer GIS ware. Among them was toady's market leaders ESRI, Intergraph, Laserscan and Autodesk etc. A sound and stable data structures to store and analyse map data became dominant in the early 1970's. This has led to the introduction of topology into GIS. Topology the related graph theory proved to be effective and efficient tools to provide logically consistent two-dimensional data representations. Another significant breakthrough occurred with the introduction and, spread of personal computers in 1980's. It was possible to have a computer the desk that was able to execute programs that previously could only be run on mainframe computers. At the same time minicomputers, and later, workstations became widely available. Relational database technology became the standard. Research on spatial data structures, indexing methods, and spatial databases made tremendous progress. The 1990's can be characterized as a period of the breakthrough of object-orientation in systemic and database design, recognition of geoinformatics as a professional activity, and spatial information theory as the theoretical basis for GIS. Potentiality of GIS is realised in the recent fast and now it has become popular among many users for variety of applications.

In India the major developments have happened for the last one-decade with significant contribution coming from Department of Space emphasizing the GIS applications for Natural Resources Management. Notable among them are Natural Resource Information System (NRIS), Integrated Mission for Sustainable Development (IMSD) and Bio-diversity Characterisation at National Level. IIRS is also playing major role-in GIS through education and training programs at the National and International level. Recently the commercial organizations in India have realized the importance of GIS for many applications like natural resource management, infrastructure development, facility management, business/market applications etc. and many GIS based projects according to the user organisation requirements. With the rise of World Wide Web (WWW), new Internet protocols such as the hypertext Transfer Protocol (HTTP), as well as easy to use interfaces (browsers), tools and languages (HTML, XML, and Java), the network becomes the system. Internet applications and Internet GIS are the system of future. A brief history regarding GIS development is given in Table no 1.

Table no 01: Historical Characteristics in GIS systems with Periods

Years	Elements	Historical Characteristics in GIS systems
-	The first maps	The roots of GIS go back hundreds, even thousands of years in the fields of cartography and mapping. Early maps are used for exploration, strategy, and planning.
1854	Early spatial analysis	In London, physician John Snow maps Cholera cases to trace the origin back to one water source
1960	Geographic computer	Throughout the 1960s, computers advance significantly in technology, speed, and design, with IBM leading the way. Early concepts of quantitative and computational geography begin to develop
1963	**The first GIS**	Geographer Roger Tomlinson begins a national land use management program for the Canadian government, inventorying natural resources. **Tomlinson** first coins the term geographic information system (GIS) and becomes known as the "father of GIS"
1965	Harvard Lab explores spatial analysis	Architect Howard Fisher establishes the Harvard Laboratory for Computer Graphics and Spatial Analysis, where some of the first GIS software, such as ODYSSEY, is invented and computer mapping applications explored. GIS pioneers such as Jack Dangermond, Carl Steinitz, Scott Morehouse, Allan Schmidt, and Allen Bernholtz participate.
1969	Design with Nature published	Ian McHarg's influential book champions a holistic, environmentally conscious approach to landscape architecture and urban planning. He introduces the "layer cake" method of stacking information that becomes fundamental to modern map overlays in GIS.
1969	**Esri is founded**	With inspiration from the Harvard Lab and *Design with Nature*, Jack and Laura Dangermond form Environmental Systems Research Institute (E.S.R.I.), now known as Esri. They begin project work, helping land use planners make better decisions with an emphasis on protecting the environment.
1972	**First Landsat satellite**	Inspired by photographs taken from space during NASA's Gemini IV mission, the US government launches the first of many Landsat satellites for Earth observation. The program provides current satellite imagery of the whole world, tied to geographic points. This becomes a major data input for GIS and begins the era of remote sensing—changing how we see the Earth
1978	**First GPS satellite**	The US launches its first GPS satellite, Navstar I, and achieves full global coverage with GPS in 1994. Other nations develop similar Global Navigation Satellite Systems (GNSS). With global coverage, virtually any

		object can report its position, and the amount of spatial data begins to grow exponentially.
1999	**First GIS Day**	Jack Dangermond, Dr. Roger Tomlinson, and students celebrate the first GIS Day at Murch Elementary School in Washington, DC. Dangermond credits Ralph Nader as the person who inspired GIS Day, now celebrated worldwide on the third Wednesday in November during Geography Awareness Week
2001	**1 million GIS users**	1 million licensed software seats and about 100,000 organizations using GIS
2005	**Google Maps**	With the advent of mapping apps like Google Maps and Google Earth, everyone can now interact with and benefit from GIS technology and it begins to become embedded in our everyday lives
2006	**Cloud computing**	Amazon Web Services is released, bringing cloud data storage to many organizations. Cloud computing had been developing for decades but is now freely available, allowing organizations to scale online operations and store larger amounts of data
2012	**ArcGIS Online is released**	The first cloud-based version of the company's GIS software. The system supports better collaboration and changes the way many GIS and technology professionals leverage mapping in their organizations.
2020	**GIS supports COVID-19 response**	Johns Hopkins University creates an ArcGIS-powered COVID-19 tracking dashboard that receives over a trillion views. The online dashboard becomes the go-to resource for monitoring the global health crisis. It inspires thousands of similar dashboards and helps people understand the pandemic, bringing GIS to the forefront of public knowledge
Today	**GIS is everywhere**	GIS is more powerful and important than ever. People make billions of maps every day using GIS. More than 95 percent of universities offer a GIS course or program. Most Fortune 500 companies, national and local government agencies, and nonprofit institutions deploy GIS

Sources: esri

COMPONENTS / ELEMENTS OF GIS:

There are many currents about the definition of GIS, as well as about its components. In general, GIS is a computer-based system, and its main components are the various elements used to operate the system. GIS components include the computer hardware, software, spatial data, data management and analysis procedures and the peoples to operate it (Figure No: 1).
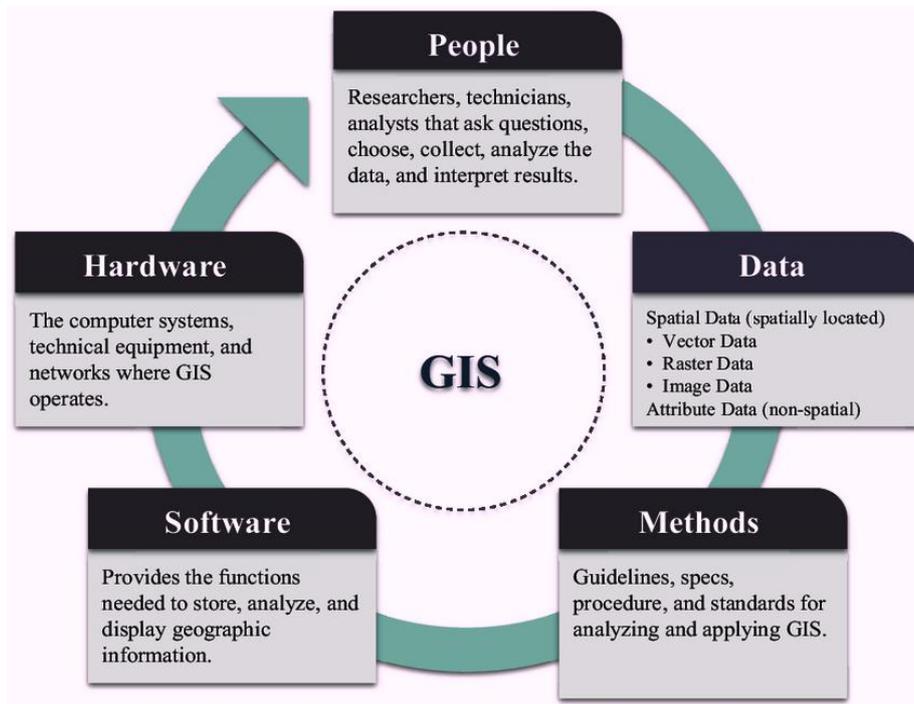
Fig. 1. Five components of GIS system, This figure were reproduced based on a figure by the Environmental Systems Research Institute, Inc. (1997).

There are five components need to be balance to function in information system satisfactory.

1. **Hardware**:

"The physical components that make of a computer system or visible parts of computer is called the hardware". "Computer hardware refers to the physical components of a computer system that can be seen and touched." It constants of the computer hardware system on which the GIS software runs. The GIS run on the whole spectrum of computer system running from the portable personal computers to multi -user supercomputers. Computer hardware is used obtain inputs, processing, output and storage of the data. Hardware refers to the external and internal devices and equipment that enable you to perform major functions such as input, output, storage, communication, processing, and more. There are two types of computer hardware: external and internal. External hardware devices include monitors, keyboards, printers, and scanners, whereas internal hardware devices include motherboards, hard drives, and RAM.

2. **Software**:

"Computer software is the computer program that tells the computer what to do" In other words, software is the system that processes data given to a computer or the invisible components of a computer that cannot be seen by the eyes or touched by the hands. The

software is the intangible part of the device that lets the user interact with the hardware and command it to perform specific tasks.

GIS software provides the function and tools that the necessary to store analysis and display geographic information data some software are ArcGIS, ArcView, ArcSDE , ArcIMS ,MapInfo, Geomatica. Some people buy the software they need for their computers, while others download it for free online.

Table no 02: Elements of GIS and Details

Sr. No	Elements of GIS	Details
1.	Hardware	**I- PC** • Type of Computer Platforms • Modest Personnel Computers • High performance workstations • Minicomputers • Mainframe computers **II- Input Devices** • Scanners • Digitizers • Tape drivers • CD • Keyboard • Graphic Monitor **III- Output Devices** • Plotters • Monitor Speaker • Printers
	Software	• Input Modules • Editing • MRP Manipulation/ Analysis Modules • Modelling Capability
	Data	• Attribute Data • Spatial Data • Remote Sensing Data

		• Global Database
	Methods	Classification, Analysis, Use of Statistics.
	Peoples/ live ware	• People responsible for digitizing,
		• implementing using GIS
		• Trained

3. **Data**:

The data name the geospatial data in GIS. The source of special data is digitizing maps, Ariel photographs, satellite image, statistical table and other related documents. Geographic data and related attribute (Tabular) data can be collected by the survey or another use of methods the digital maps from is the basic data input for GIS. Data relay to the map object can also be attached to the digital map data.

4. **Methods**:

A computer system for GIS consists of hardware, software and method design to support the data capture, storage, processing, analysis Modelling and display of geo - special data. Successful GIS operators offered to the will designed plan and business rules which are the model and operating particular unique to each organisation.

5. **Peoples/ live ware /Users:**

The last component of a GIS system is the user. It mainly consists of two types of users, skilled and unskilled, from the perspective of the people. This system mainly requires skilled users. In a GIS system, the person who uses the GIS software or GAS is called the user. He is mainly known as a GIS engineer. People are user of Geographic Information System they can be handle all the tasks in GIS software. Users can maintain to design and technical specification. It has limited value without the people who manage the system and develop plans for applying it to real-world problems. GIS user is called GIS Engineer.

CONCLUSION:
Geographic Information Systems (GIS) have undergone a remarkable transformation since their conceptual origins in mid-20th-century efforts to automate spatial analysis and land management. From John Snow's seminal 1854 cholera map, which demonstrated the power of spatial pattern recognition in solving real-world problems, to Roger Tomlinson's

pioneering Canada Geographic Information System (CGIS) in the 1960s—the first operational GIS—and the subsequent commercialization and democratization of the technology through organizations like ESRI in the 1980s, GIS has evolved from specialized, mainframe-dependent tools into versatile, accessible platforms integral to modern decision-making. At its core, GIS remains defined by the seamless integration of five essential components: hardware (encompassing computing devices, sensors, and positioning technologies like GPS), software (ranging from proprietary suites like ArcGIS to powerful open-source alternatives), data (spatial geometries paired with rich attribute information), people (the analysts, domain experts, policymakers, and end-users who interpret and apply insights), and methods (the analytical procedures, models, and workflows that turn raw data into actionable knowledge).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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REFERENCE:

1. Basudeb Bhatta, 2008, Remote Sensing and GIS, Publisher, OUP India.

2. Kali Charan Sahu, 2024, Remote Sensing and Geographical Information Systems, Publisher: Atlantic Publishers & Distributors (P) Ltd.

3. P.R. Vyas, 2015, Remote Sensing and Geographical Information Systems: Basics and Applications, Publisher: Rawat

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