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GIS in Civil Engineering: Yesterday, Today and Tomorrow

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Abstract

A GIS (Geographical Information System) is basically a computerized information system in which all information must be linked to a geographic reference. Because the potential uses for GIS in Civil engineering practice are numerous, interest in and utilization of GIS technology is increasing rapidly. In this paper we purposed the framework of civil engineering projects with the application of GIS and then summarize the role of GIS in civil engineering.

Keywords: *GIS, survey, wetland, data overlay, topography.*

1. Introduction

Civil engineering is the oldest branch of the profession of engineering that deals with planning, design, construction and maintenance of the built environment on which society depends. It can be classified into two broad types of civil engineer leaders: those who work in creating visible infrastructures such as buildings, highways, bridges, airports, ports, waterways, and dams; and those who work behind the scenes such as in building foundations, water treatment plants, water supply pipe systems, ecological restoration and underground drainage systems. [1]

John Snow, an English physician, in 1854, cholera outbreak used points to represent the locations of some individual cases, possibly the earliest use of a geographic methodology in epidemiology. His study of the distribution of cholera led to the source of the disease, a contaminated water pump within the heart of the cholera outbreak. [2]

The first computerized GIS began its life in 1964 as a project of the Rehabilitation and Development Agency Program within the government of Canada. The Canada Geographic Information System (CGIS) was designed to analyze Canada's national land inventory data to aid in the development of land for agriculture. [3] The CGIS project was completed in 1971 and the software is still in use today. Also, the CGIS project involved a number of key innovations that have found their way into the feature set of many subsequent software developments.

From the mid-1960s to 1970s, developments in GIS were occurring mainly at government agencies and universities. In 1964, Howard Fisher established the Harvard Lab for Computer Graphics where many of the industries early leaders studied. The Harvard Lab produced a number of mainframe GIS applications. ODYSSEY was the first modern vector GIS and many of its features would form the basis for future commercial applications.

Automatic Mapping System was developed by the United States Central Intelligence Agency (CIA) in the late 1960s. This project then spawned the CIA's World Data Bank, a collection of coastlines, rivers, and political boundaries, and the CAM software package that created maps at different scales from this data. This development was one of the first systematic map databases. In 1969, Jack Dangermond, co-founded Environmental Systems Research Institute with his wife Laura. ESRI would become in a few years the dominate force in the GIS marketplace and create ArcInfo and ArcView software. The first conference dealing with GIS took place in 1970 and was organized by Roger Tomlinson and Duane Marble. Today, numerous conferences dealing with GIS run every year attracting thousands of attendants.

In the 1980s and 1990s, many GIS applications underwent substantial evolution in terms of features and analysis power. Many of these packages were being refined by private companies that foresaw the future commercial potential of this software. It was during this period that many GIS applications moved from expensive minicomputer workstations to personal computer hardware.

Geographic information system--an integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. [4]

An advanced information system like GIS plays a vital role and serves as a complete platform in every phase of infrastructure life cycle. Advancement and availability of technology has set new marks for the professionals in the infrastructure development areas. Now more and more professionals are seeking help of these technologically smart and improved information systems like GIS for infrastructure development. Each and every phase of infrastructure life-cycle is greatly affected and enhanced by the enrollment of GIS. [5]
A geographic information system is a facility for preparing, presenting, and interpreting facts that pertain to the surface of the earth. [6]

2. Civil Engineering Project Frameworks

GIS software provides civil engineers with the framework for maintaining and deploying critical data and applications across every aspect of the infrastructure project life cycle including planning and design, data collection and management, spatial analysis, construction, and operations management and maintenance. [7]

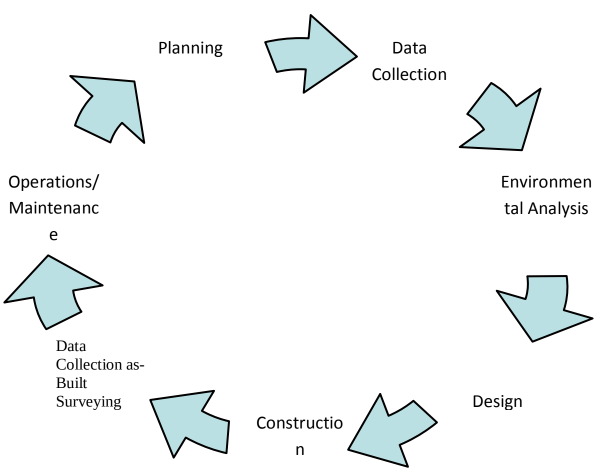

Fig. 1: Different Phases of Project life Cycle

2.1 Planning

In this we plans functions such as environmental impact, economic analysis, alternative sitting analysis and routing utilities.

2.2 Data Collection

It collect precise site data for field survey, topography, soil, subsurface geology, traffic photogrammetric, environmental area, wetlands, hydrology and other specific design data.

2.3 Environmental Analysis

It includes hydrology analysis, volume calculations, soil load analysis, traffic capacity, environmental impact, slope stability, materials consumption, erosion control, and air emissions. During environmental analysis, view project maps, site photos, CAD files, and survey measurements.

2.4 Design

This phase includes including grading, contouring, specifications, cross sections, design calculations, mass haul plans, environmental mitigation plans, and equipment staging. This includes integration with traditional design tools such as CAD and data -bases for new design capabilities

2.5 Construction

This phase includes the management for building the infrastructure includes machine control, volume and material, earth movement, volume and material, and payment calculations; materials tracking; logistics; schedules; and traffic management

2.6 Data Collection as- Built Surveying

This phase includes as-built surveying infrastructure data, operators use defined, operational

2.7 Operations/Maintenance

The topological characteristics of a GIS database can support network tracing and can be used to analyze specific properties or services that may be impacted by such events as stoppages, main breaks, and drainage defects.

3. Applicability of GIS in Civil Engineering Project Framework

GIS is playing an important role in civil engineering, IT supports all phases of the a project life cycle .GIS software is interoperable, supporting the many data formats used in the life cycle and allowing civil engineers to provide data to various agencies in the required format while maintaining the data's core integrity

3.1 Planning

Economic analysis

In this paper [8] author presented some initial suggestions for the ways in which GIS may be important to economics and the GIS related issues concerning which applied economists could provide useful insights. Applied economists could make contributions to both the science and technology of GIS in at least two primary areas. The first of these is in the application of GIS to those problems with which applied economists generally concern themselves. The second involves active reflection and understanding of the broader conceptual issues, including valuation, generated by the growing use of GIS within our society.

In this paper [9] Geographical Information Systems are used for inputting, storing, managing, analyzing and mapping spatial data. This paper also argues that each of these functions can help researchers interested in spatial economics.

Routing utilities

This paper [10] makes the assertion that vehicle routing rearch has produced increasingly more powerful problem solvers, but has not increased the realism or compexity of typical problem instances. This paper argues that the time has come of use realistic street network data to increase the relevence and challenge of our work.

This paper, [11] observe the value of real-time traffic information gathered through Geographic Information Systems for achieving an optimal vehicle routing within a dynamically stochastic transportation network. We present a systematic approach in determining the dynamically varying parameters and implementation attributes that were used for the development of a Web-based transportation routing application integrated with real-time GIS services.

Data overlay

Overlay is a fundamental spatial operation. It is one of the functions that distinguish GIS from other systems such as CAD and DBMS. Overlay operators combine data from the same entity type or different entity types. In both cases they create new geometries and can change entity type and/or attribute value.

Hydrological Modeling

This paper [12] endeavor to present the larger scheme of the benefits for the applications of GIS in water resources and hydrological modeling in particular.

A GIS provides the framework within which spatially distributed data are collected and used to prepare model input files and evaluate model results. The Automated Geospatial Watershed Assessment tool (AGWA) uses widely available standardized spatial datasets that can be obtained via the internet. The data are used to develop input parameter files for KINEROS2 and SWAT, two watershed runoff and erosion simulation models that operate at different spatial and temporal scales.[13]

3.2 Data collection

Field survey

This paper [14] describes the use of current geospatial handling technology to manage captured and processed survey data and other information in the Department of Surveying and Mapping Malaysia. A range of solutions have been developed for the management of survey and mapping information covering cadastral data, topographic and mapping data, aerial photographic images and geodetic information within Kuala Lumpur, the capital city of Malaysia.

Topography

The dataset presented in this paper [15] consists of the areal extent of the five new AOIs, two subareas, and the extended Kandahar AOI, elevation contours at 100-, 50-, and 25-meter (m) intervals, an enhanced DEM, and a hydrographic dataset covering the extent of the new study area. The resulting raster and vector layers are intended for use by government agencies, developmental organizations, and private companies in Afghanistan to assist with mineral assessments, monitoring, management, and investment.

Subsurface Geology

This paper [16] deals with the main aspects of geological and geo-morphological hazards assessment by presenting review of GIS-based methodology for identification and analysis of environmental hazards of such type to which the Daugavpils and Ilūkste districts are ex

Traffic

This paper [17] discussed about the GIS Software, as to determine the optimal routes or Best routes from one origin to many destinations kind of problem, with an objective of minimizing travel distance and travel time of users. Constrains taken into consideration were impedance for intersections, type of road and speed. GIS emerged as better tool for getting solution of such complex problems very accurately and rapidly.

Photogrammetric

Geospatial tools include utilizing imagery data sets through photo grammetry and analyzing remotely sensed data. Data sets may be collected through active sensors, such as RADAR or LIDAR, or passive sensors, which collect multi- or hyper-spectral imagery. The processing of these data sets can result in detailed data files representing the terrain or geological and soil maps, to name only a few. Data sets can be combined with both coordinate and attribute data collected in the field and processed geospatially using Geographic Information Systems, a combination of computer hardware, software and data that allows information to be organized around a specific location [18].

Wetlands

In this paper [19] the spatial soil resource information generated through remote sensing and ground survey was combined with other related data in GIS to derive a land use plan for Majuli Island in the Brahmaputra valley, Assam. Six landforms were delineated in floodplains.

3.3 Environmental Analysis

Volume Calculations

In this paper [20] focuses on 3D capabilities of GRASS GIS providing new 3D tools to manipulate analyse and model 3D landscape phenomena. Also investigate the options of modeling dynamic processes occuring in soil using simple 3D map algebra algorithms.

Environmental Impact

In this paper [21] present the GIS system for the analysis of the numerical weather prediction data. This kind of data has multidimensional character (three dimensions and time) and its analysis should consider all the available factors. Proposed GIS system consists of RASDAMAN application with implemented OLAP cube mechanism, which enables the user to process data in the spatial-time domain.

Slope Stability

This paper [22] purposed a GIS-based kinematic model to address slope stability for a canyon landfill in southern California. Geologic data is compiled into the GIS to create a representative model of the geologic structure across the study area. Spatial analysis of the geologic model and the topographic model determine kinematic slope stability and identify areas of potential plane failure or wedge failure

In this paper [23] designed a model, with objectives to explore different types of mass wasting processes using on-line resources and recent mass wasting events; to evaluate the sensitivity of slope stability to topographic and earth material variables according to the infinite slope method; and assess the spatial variation in slope stability using a Geographic Information System . The final objective will focus on the urbanized area of Cincinnati and Hamilton County in southwestern Ohio.

Soil Erosion control

In this paper [24] GIS improve the management of the geo-spatial data and support the decision making and planning of land use in watershed. The objective of this research is to study the effect of geo spatial characteristics on degrees of rocking weathering and soil erosion in Kheow Nio waterland.

Air emissions

This paper [25] presents a preliminary study for the evaluation of transport-related air pollution situations in an urban area. The authors utilize a geographic information system (GIS) which integrates a vehicle emission model, pollutant dispersion model, backward trajectory model and related databases to estimate the emissions and spatial distribution of traffic pollutants in Taichung, Taiwan, ROC.

3.4 Design

Water System

The integration of remote sensing and GIS techniques has enabled assessments of NPS pollution, aquatic vegetation growth, salt marsh quality and floodplain disturbances over time. It is worth emphasizing that the procedures employed for these studies can be extended to many water resources related problems in the Southeast, provided careful consideration is given to source materials, database construction and GIS analysis techniques. [26]

3.5 Construction

Earth movements

In this paper, [27] the earthquake-engineering problem was analyzed using object-oriented analysis technique from the two points of view which are macroscopic one of earthquake disaster prevention and microscopic one of aseismic design of building, and the usefulness of GIS was shown through the introduction of application cases developed by ourselves

This paper [28] presented a real-time operative decision support computer system named Shyska. The system applies the potential of GIS to processing information to different space-time scales. It integrates spatially-distributed hydrological models, oriented to runoff simulation and prediction, using topographical attributes extracted from a DEM. Its final aim is to assist Hydrological Information Automatic Systems (SAIH) in Spain, facilitating information management and use in real-time during alert and flash-flood situations typical of Mediterranean environments.

Intermediate construction

In this paper [29] application of Geographic Information Systems (GIS) in construction disaster relief planning is presented. A case study of GIS developed for Fulton County in the state of Georgia is presented. The project identifies potential resource allocations and accessible roads network using TranCAD GIS computer program.

3.6 Data Collection as – Built Surveying

Reducing Errors

This is not the case of reality that, while using GIS to analysis spatial data, this data wiil be completely accurate. Some steps can be taken to reduce the impact of certain type of errors; they can never be completely eliminated. So we have to looking at data to describe data quality.

Logistics

Miller, Wu and Hung [30] define time-critical logistics (TCL) as the time-sensitive procurement, processing and distribution activities. Transportation networks that contain these logistic systems act as a confounding factor. This paper reports on the development of a GIS-based decision support system for dynamic modeling of congestion and routing in a TCL scenario. The system predicts network flows at detailed temporal resolutions and determines the departure time and shortest path required for a shipment to reach its destination by a given deadline. The GIS provides effective decision support through its database management capabilities, graphical user interfaces and cartographic visualization. The model developed in this paper also helps to simulate 5 various scenarios of network disruptions.

3.7 Operations/Maintenance

GIS is used in engineering, environmental science, land surveying, urban planning and emergency management.

4. Summarization

Today, geographic information systems are commonly used for everything one can imagine, from basic mapping to supporting resource exploration and development, from environmental management to the planning and administration of transportation and telecommunications systems, utility infrastructures, urban development and land use.

Table1. Summarization of GIS applications in different Project phases

S. No.	Phases	Applications	References
1.	Planning	Environmental impact economic analysis, alternative sitting analysis, routing utilities, data overlay, modeling, and benefit/cost alternatives analysis.	[8-13]
2.	Data Collection	Field survey, Topography, Soils, Subsurface geology Traffic, Photogrammetric, Wetlands.	[14-19]
3.	Environmental Analysis	Hydrology analysis, Volume calculations, Soil load analysis, Traffic capacity, Environmental impact, Slope stability, Materials consumption, Erosion control, Air emissions, Site , Photos, project maps, CAD files.	[20-25]
4.	Design	Hydraulic calculators, Water System.	[26]
5.	Construction	Machine Control, earth movements, Intermediate construction	[27-29]
6.	Data Collection as-Built in Surveying	Built surveying, eliminating costly data conversion, Reducing Erros.	[30]
7	Operations / Maintena	engineering, environmental science, land surveying, urban planning and emergency management.	--------

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5. Conclusion

GIS allows civil engineers to manage and share data and turn it into easily understood reports and visualizations that can be analyzed and communicated to others. This data can be related to both a project and its broader geographic context. It also helps organizations and governments work together to develop strategies for sustainable development. Thus, GIS is playing an increasingly important role in civil engineering companies, supporting all phases of the civil projects.

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