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Jerzy Stanik[1], Maciej Kiedrowicz[2]

USING THE CAPABILITIES OF AI IN THE LIFE CYCLE OF A GIS SYSTEM

Abstract: The article attempts to explain how developed technologies, techniques and methods of artificial intelligence can be used in the life cycle of GIS systems or conducting GIS projects for compliance with currently applicable standards. Through comprehensive source research, literature reviews, and interviews with experts, this article describes current research gaps related to the conduct of a GIS project that need to be explored further. In this way, several research questions were formulated, and attempts were made to provide meaningful answers to them. The overall research question is whether artificial intelligence (AI) makes significant changes to the lifecycle trajectory of a GIS-class system, and whether it can have a significant impact on the time, cost, and quality of a GIS project.

Keywords: GIS, system life cycle, AI, earned value method

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[1] Military University of Technology, Faculty of Cybernetics, Warsaw, Poland, ORCID ID: https://orcid.org/0000-0002-0162-2579, email: jerzy.stanik@wat.edu.pl

[2] Military University of Technology, Faculty of Cybernetics, Warsaw, Poland, ORCID ID: https://orcid.org/0000-0002-4389-0774, email: maciej.kiedrowicz@wat.edu.pl

Introduction

Artificial Intelligence (AI) combined with location intelligence is how we can deliver on the promise of AI: save time, increase the value of data and images, and make informed decisions faster. And the combination of AI with geographic information system (GIS) technology provides real-world context for operations. Artificial intelligence in the process of designing architecture and improving GIS systems is a topic that enjoys great interest and development. AI in the life cycle of GIS systems is a topic that concerns the use of artificial intelligence to improve the basic parameters of a GIS project, such as time, cost, quality and cybersecurity. GIS data/information assets and computer systems are one of the most valuable assets of GIS organizations or users today. Their protection has become a priority, and the business – its maintenance and success – depends on its effectiveness (Coresite, 2016). Artificial intelligence, capable of processing large amounts of data and identifying complex patterns, is crucial not only for strengthening cybersecurity defenses, but can also significantly support GIS implementation projects in terms of compliance with international standards, privacy, or any other type of compliance. AI systems excel at real-time data analysis, enabling fast and effective support for activities throughout the GIS system lifecycle, from the planning, construction and implementation stages to the operation and improvement stages. AI in GIS improvement has both positive and negative aspects that need to be considered when planning and executing GIS projects. It is important to note that while AI can greatly help drive a GIS project, it should be implemented alongside other technologies, e.g. DevOps, combining software development (DEV) and IT operations (OP), aimed at shortening the development lifecycle of GIS computer systems and ensuring the continuous delivery of high-quality software.

This article aims to review the state-of-the-art AI means [technologies, techniques, and tools] and indicate their use in the implementation of modern GIS projects. Through comprehensive source research, literature reviews, and expert interviews, this article describes the opportunities and challenges facing artificial intelligence (AI) in relation to the GIS-class system lifecycle. The article also aims to logically guide the reader through the process of designing GIS architecture and indicate places where the time and effort of project tasks can be reduced in the GIS life cycle.

Background

Context. GIS, or Geographic Information System, is a technology that allows you to create, manage, analyze, and map various types of data. The life cycle of a GIS class system is a concept based on spreading over time specific works related to the development, production and operation of a GIS computer system. In other words, it is a cycle covering the period from the need to build and implement such a system to its decommissioning. The most common/universal model that can be adapted to different contexts and domains to achieve continuous improvement and efficiency is the PDCA model/cycle. The PDCA cycle is a continuous process improvement model that can also be applied in the context of GIS (Geographic Information System) systems. This model consists of four phases (Fig.1):

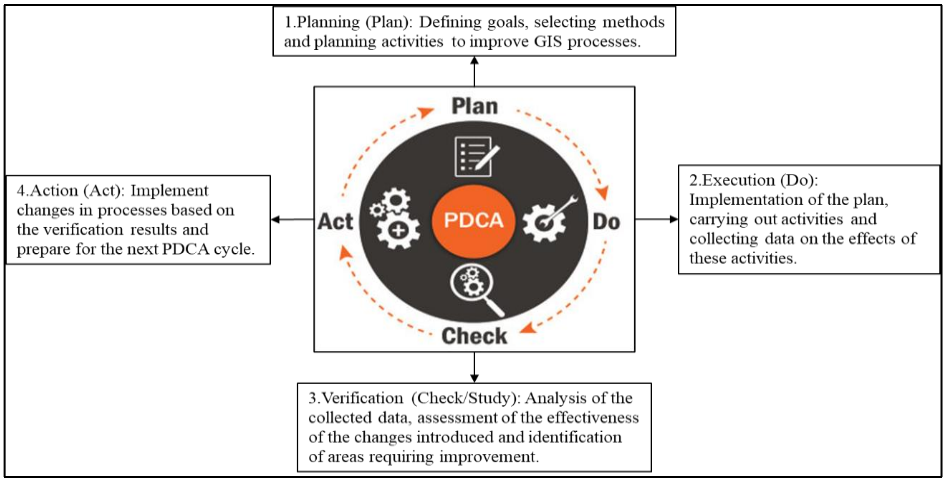

Fig. 1. The PDCA cycle in the context of GIS systems
Source: Own study

The implementation of a GIS class system should be treated as a PROJECT, while a GIS Project should be understood as a temporary undertaking aimed at obtaining a GIS computer system or its components in accordance with the requirements of an appropriate compliance standard, e.g. Open Geospatial Consortium (OGC):

1. Geographic databases: Stores information about geographic features, their locations, and attributes.
2. Computer hardware: necessary for data processing and analysis.
3. GIS software: enabling manipulation and analysis of spatial data.
4. GIS creators and users: who develop and use systems for their needs.

The life cycle of a GIS project, as in the case of other projects, includes several key stages that are necessary for its effective implementation (Wysocki, 2013).

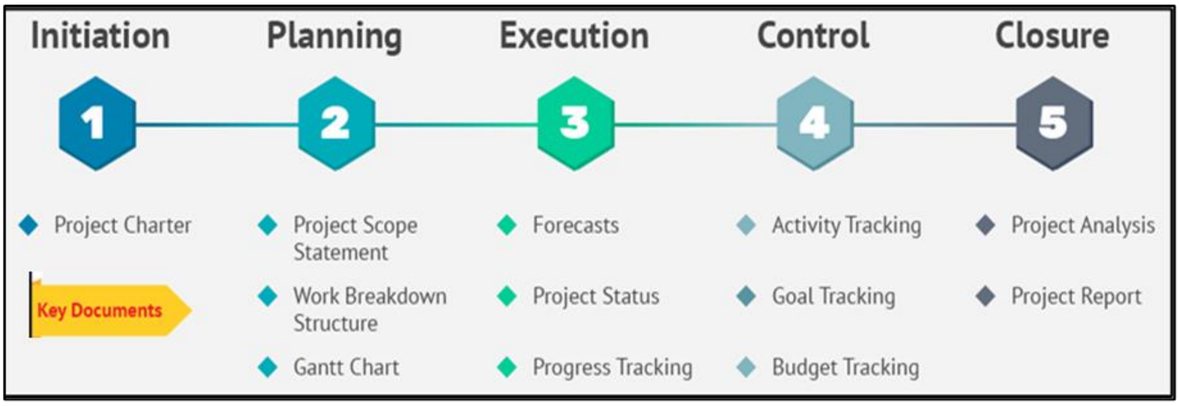

Fig. 2. GIS project lifecycle model
Source: Own study

Table 1. Characteristics of the stages of the GIS project life cycle

Stage name	Description
1. Initiation	This is the stage at which the objectives of the project, the scope of work and the resources necessary for its implementation are defined. For a GIS project, this may also include choosing the right geospatial technologies and tools.
2. Planning	At this stage, a detailed project plan is created, which includes a schedule of activities, budget, risk management plan and work methodology. In GIS projects, it is also important to plan how spatial data is collected, processed, and analyzed.
3. Implementation	This is the phase in which the project team executes the planned activities. In the case of GIS, this can include collecting field data, digitally processing it, creating spatial models and maps.
4. Monitoring and control	At this stage, the progress of work against the project plan is regularly checked, changes are managed, and the performance of the project team is monitored.
5. Conclusion	The last stage, where the project is formally closed. In the case of a GIS project, this may mean handing over finished geospatial products to the client, final documentation and project evaluation.

Source: Own study

Each of these stages has its own specific tasks and challenges, and the success of the project depends on the effective management of all of them[2] and the management of the level of risk in such a way as to keep the project parameters within tolerance. It is also worth noting that the success of a GIS project can be measured by the impact of risk management on:

1. Project Completion Time: Compare the planned time with the actual project completion time.
2. Budget adherence: Monitoring that spending is within budget.
3. Quality of deliverables: Evaluate the quality of project deliverables against expectations and standards.
4. Customer satisfaction: Measure customer satisfaction through surveys and feedback.
5. Team satisfaction: Assessing the morale and commitment of team members.

Figure 3 shows the GIS Project Lifecycle Model linked to the GIS Product Lifecycle Model for risk management to keep baseline parameters within accepted tolerances.

Research gaps in maintaining basic design constraints such as time and cost often relate to optimizing these parameters without compromising design quality. One area that may require further research is the integration of the product life cycle model into the GIS project management lifecycle. Another area could be the introduction of new technologies, such as AI. In the latter case, the research problem is to optimize the time and cost management process of the GIS project by using effective AI tools to support the GIS project management cycle to implement the individual steps of this process.

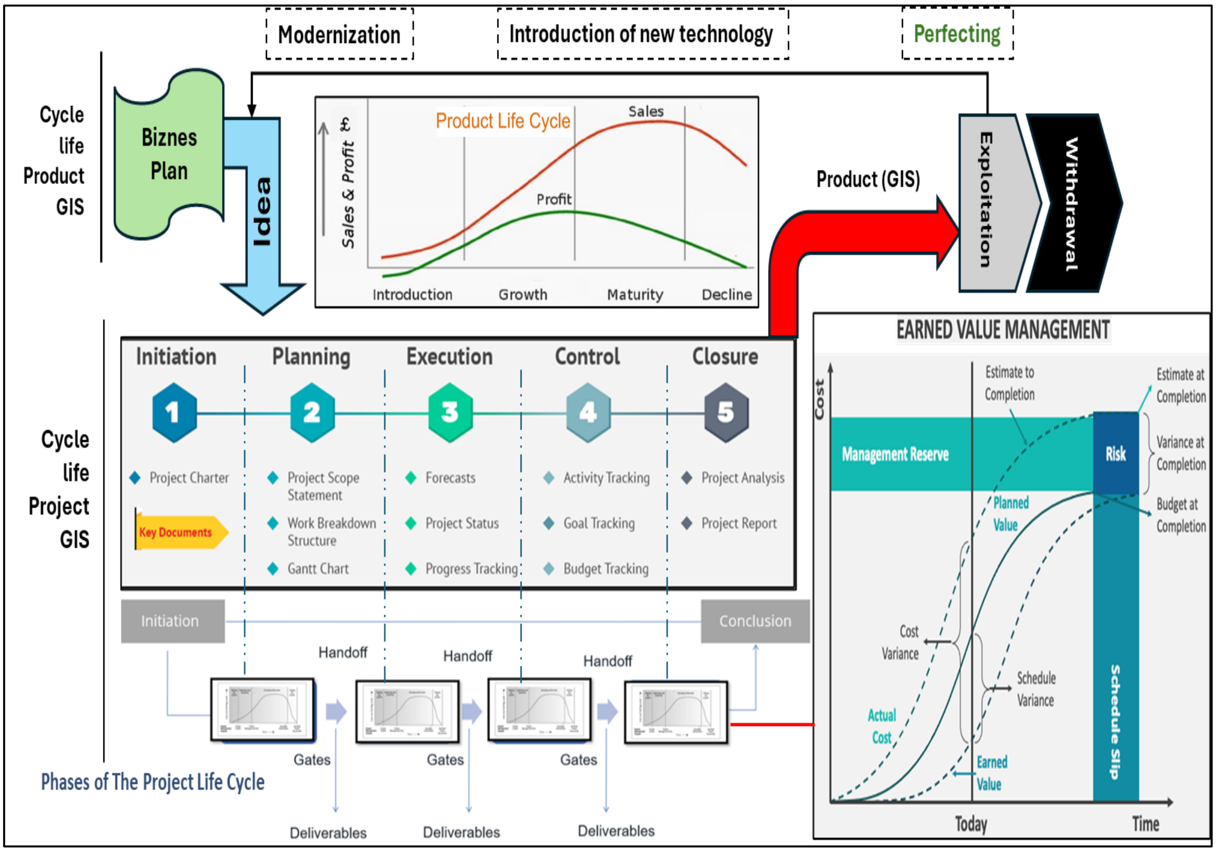

Fig. 3. GIS lifecycle model to measure the impact of risk management
on core project parameters
Source: Own study

Definition of a research task. The main goal of the authors of the article is to present the latest professional literature and the latest research on the contribution of AI technology to the engineering of GIS computer systems. This review also identifies gaps that need to be further investigated. In this way, three research questions were formulated:

RQ1. Does the use of artificial intelligence in a GIS project significantly change the trajectory of its design methodology and GIS architecture and its implementation?

RQ2. Does the use of AI change the stages or steps in the life cycle of a GIS project?

RQ3. Does artificial intelligence have a significant impact on changing the basic parameters of a GIS project?

RQ4. How and to what extent can AI replace the tasks of the design and implementation team?

RQ1 and RQ2 are designed to explore what types, domains, components, or algorithms of artificial intelligence are, or can be used, in the context of GIS system engineering. RQ3 and RQ4 are designed to determine what AI tools can be used in running a GIS project to keep track of the project's primary success metrics: In scope (what?), On time (when?), In budget (for how much?), According to quality parameters.

According to the authors:

1. The use of artificial intelligence (AI) in a GIS project has the potential to change the trajectory of manufacturing methodology. Artificial intelligence can bring several

benefits to the process of running a GIS project. However, it is important to remember that AI should be used as a tool to support the trajectory of ISMS implementation, and not as a replacement for a compliance standard or human expertise. Human involvement and decision-making in accordance with the adopted compliance standard are still crucial in interpreting AI-generated insights and implementing appropriate safety measures.

2. The use of artificial intelligence (AI) in a GIS project does not necessarily change the steps or steps of GIS design and implementation. Appropriate project management compliance standards, e.g. PRINCE 2, provide a framework for the establishment, implementation, maintenance and continuous improvement of GIS, regardless of specific AI technologies or tools.
3. The use of artificial intelligence in an ISO 27001:2022 project can affect the time, cost, and quality of implementation. Here are a few things:
   a. Time: AI can help automate certain tasks and processes, reducing the time it takes for manual work. For example, AI can help automate risk assessment, vulnerability scanning, or incident response. This can speed up the deployment process and allow for more efficient resource allocation.
   b. Cost: While the initial investment in AI technologies and tools can increase upfront costs, it can potentially lead to long-term savings. AI can help streamline processes, reduce human error, and improve efficiency, resulting in cost savings over time. However, it is important to carefully evaluate the cost-benefit analysis before implementing AI solutions.
   c. Quality: AI can improve the quality of your deployment by providing more accurate and consistent results. For example, AI-powered tools can help you identify vulnerabilities or anomalies more effectively than manual methods. This can lead to better risk management and a better overall safety posture.

Materials and Research Methods

The findings and results presented in this paper are based on two methods:

1) review of articles, in particular reports containing the results of various types of surveys addressed to GIS and GeoAI specialists,
2) A pilot study by interviewing GIS engineering specialists and GeoAI experts in GIS.

Article review method. Literature review was a key element of the research work, as it allowed to build a solid theoretical foundation for research, identify existing gaps in knowledge, and justify the need for further research. It was also a good way to show that the authors are up to date with current trends and developments in this field.

The method used is understood as a process of systematic search, evaluation and interpretation of available scientific papers and publications related to the study of the possibility of using AI techniques and tools in improving the trajectory of the GIS system life cycle model and improving its quality, costs and duration.

The method used is academic research, understood as a systematic effort aimed at acquiring new knowledge in the domain of GIS and AI, and boils down to a systematic search for relevant information on AI tools and technologies supporting the implementation and certification of GIS for compliance with project management standards.

In this review, the authors have included the latest, compliance norms, standards, codes of conduct and specialist journals on the life cycle of GIS and GeoAI in GIS systems and published in the most popular knowledge bases, peer-reviewed scientific journals and doctoral dissertations – hereinafter referred to as "articles".

The research includes all "articles" that described technologies or tools in the field of AI, and which were undertaken to answer the main research question, "can AI play a significant role in the GIS lifecycle?" and how.

Selection criteria and results of the review of articles. The scope of research of the article covers the period from 1 January 2010 to 30 April 2024. The criteria for the audit studies were predefined to eliminate ambiguity in the selection process. Therefore, the following inclusion criteria were considered:

- The articles focus on cybersecurity issues;
- The articles focus on the issues of artificial intelligence;
- Articles are peer-reviewed.

The following criteria determine when work has been excluded:

- Articles are not written in English;
- The articles are not available in full text;
- The papers are duplicates of other studies.

The results of the article review are presented in Table 2.

Table 2. Results of the article review

Digital library	Pre-selection	Inclusion/Exclusion criteria	Titles and keywords	Summaries	Choosing a full text
IEEE Xplore	21	15	3	3	3
Springer	61	22	12	10	7
Science Direct	21	6	5	5	4
ACM	18	4	2	2	1
Wiley Library	21	7	6	5	3
ResearchGate	30	12	4	4	3
SemanticSholar	73	21	6	5	4
Together:	**245**	**97**	**38**	**34**	**25**

Source: Own study

Pilot test method. In parallel with the literature review, a pilot study was conducted, interviewing GIS engineering specialists and experts in GeoAI in GIS. This research strategy was qualitative and interpretative in nature. The empirical data include six semi-structured thematic interviews. The respondents were selected by the method of deliberate sampling. Using knowledge and experience in the field of artificial intelligence and cybersecurity, a group of high-ranking authorities in the field of research, data analytics and consulting was selected as a requirement for participation. A more detailed overview of the empirical data is provided in Table 3 below. Each expert was asked a similar set of questions, while giving the interviewee the freedom to focus on the aspects that interest him. The results of the review of empirical data are presented in Table 3.

Table. 3. Empirical Data Review

Informant	Position	Total duration of the interview	Number of questions asked
Expert 1	Research Professor of AI	3 hours	16
Expert 2	GIS Specialist	3 hours	25
Expert 3	GIS Project Manager	2 hours	13
Expert 4	AI Compliance Manager	2 hours	18
Expert 5	Expert ds. GeoAI	4 hours	17
Expert 6	Architect GIS	3 hours	26

Source: Own study

The survey prioritized respondents with in-depth knowledge of GeoAI technology. Respondents' job descriptions were a mix of executives, ranging from analyst/manager to senior management.

Result and discussion

Elements of good practice and standards for GIS systems. It is widely believed that "good practices" are actions that bring concrete and positive results, are durable and repeatable, and can be applied in similar conditions elsewhere or by other entities (Dobre praktyki (*Good practices*)). These practices have led to the development of international GIS standards, which are widely used to ensure the interoperability and compliance of geographic information systems (GIS) around the world. Table 4 shows some key organizations and standards.

These standards and specifications are critical to ensuring that GIS systems can communicate effectively with each other, regardless of the platform or country in which they are used.

GIS manufacturing compliance standards can cover a variety of aspects, such as data quality, file formats, metadata, computer systems engineering principles, interoperability, and compliance with regulatory and industry standards.

Table 4. Key Organizations and Standards

Name	Description
Open Geospatial Consortium (OGC)	It is an international non-profit organization with more than 450 companies, government agencies, and universities. OGC collaborates on the development and implementation of open standards for spatial data and services. OGC standards are widely used and enable the interoperability of various IT systems (Technical guidelines…).
ISO/TC 211 Geographic Information/ Geomatics	It is an ISO technical committee that deals with geographic information and geodesy. It is working with the OGC to develop geospatial standards (Open GIS…).
INSPIRE	In Europe, the INSPIRE Directive establishes a framework for a common infrastructure for spatial information in the European Union to support environmental policy and activities aimed at sustainable development.
Esri	Esri, the developer of ArcGIS, is committed to open standards compliance and interoperability. ArcGIS supports more than 100 nonspatial standards, data formats, and services (Open Geospatial Consortium).

Source: Own study based on: Web Map Service

Life cycle model of a GIS object. The Geographic Information System (GIS) lifecycle model is a concept that describes the stages that a GIS system goes through from its planning to its decommissioning. This model helps you manage and optimize your GIS-related processes. Here is a typical detailed GIS life cycle model (Fig. 4).

It is worth noting that in practice, the GIS lifecycle can be more complex and iterative, with the possibility of going back to earlier stages to make the necessary modifications or improvements. In addition, in the context of ArcGIS, there are specific lifecycles for ArcGIS Living Atlas content that are independent of the ArcGIS Enterprise lifecycle and include updates and support for mature products (Living Atlas content lifecycles and updates – Portal for ArcGIS). It is worth noting that from the point of view of time and effort of work, the most important components in the GIS life cycle are the design process and the system architecture configuration process. The GIS architecture design process (Fig. 5) aligns the identified business requirements (user needs) from business strategy, goals, and drivers (business processes) with the identified recommendations for business information system infrastructure technology (networks and platforms). The system architecture design translates business needs into identified IT requirements. Hardware requirements are generated based on the peak workloads of software processing. Network connectivity requirements are generated based on peak data flow.

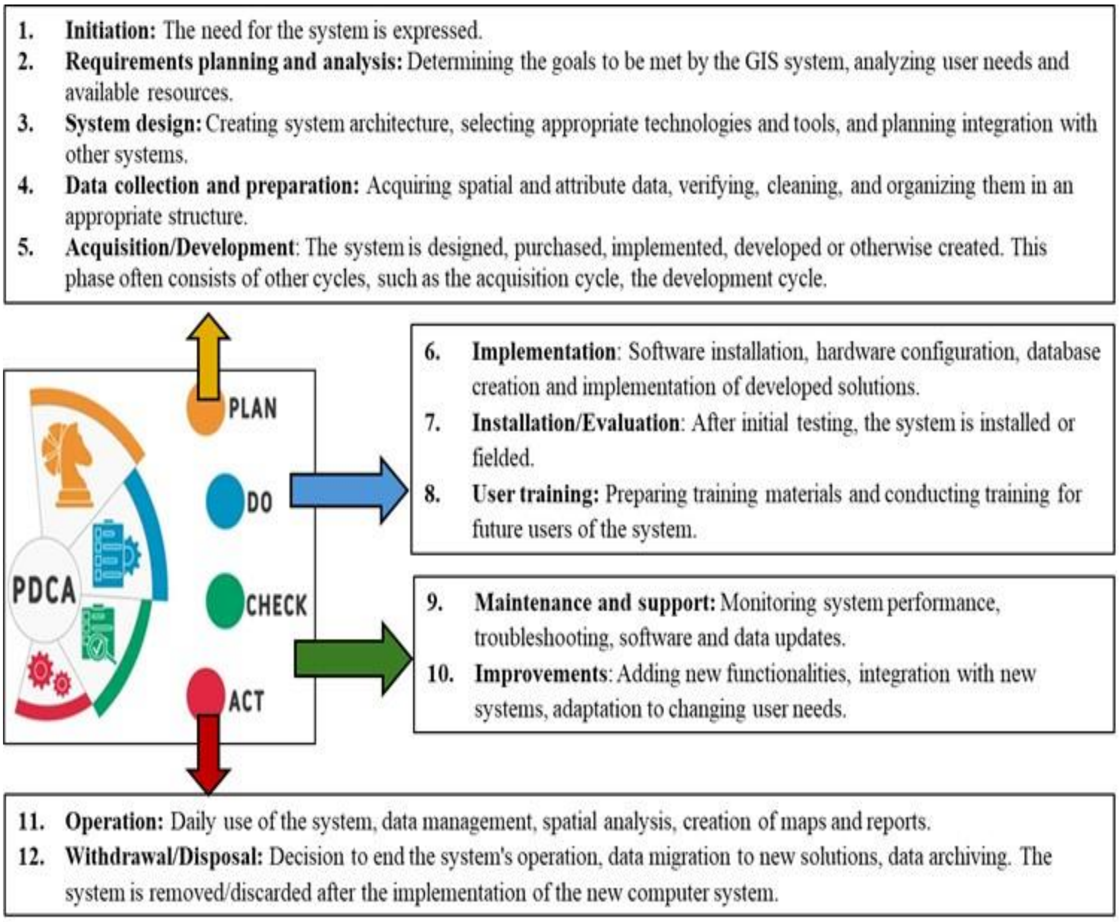

Fig.4. GIS life cycle diagram
Source: Own study

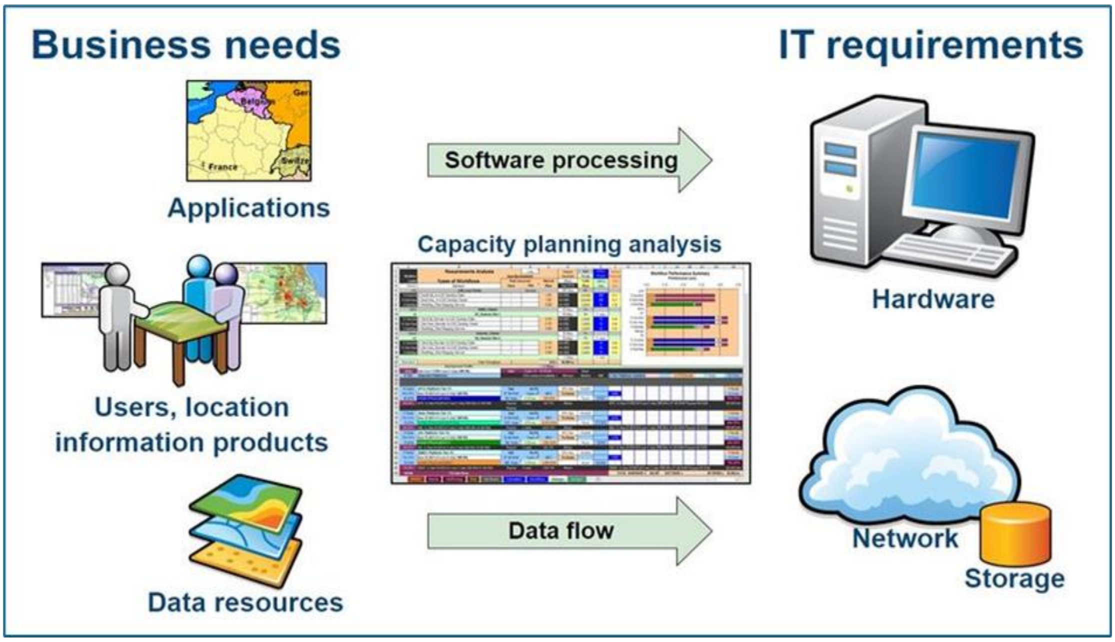

Fig. 5. GIS Architecture Design Diagram
Source: Own study

A detailed overview of the GIS life cycle stages, including the percentage of time and effort (this data is also based on contextual knowledge from additional research conducted by the following companies: GISonLine, ProfitoData, GISPartners), is presented in Table 5.

Table 5. Overview of GIS lifecycle stages

Phase	Description	Share %	Time Duration
The Initiation phase	All GIS projects have a starting point, which is commonly referred to as the initiation phase. During this phase, the organization establishes the need to use a specific type of system for GIS and documents its purpose. The information to be processed, transmitted, or stored in the system is usually evaluated, as well as who will require access to it and how this access will be provided (in general). Once these tasks are completed and the need for a new or improved GIS is determined, several processes need to be completed before the project is approved.	2 to 5	from a few weeks to a few months
Development/acquisition phase	In this phase, the system is designed, purchased, programmed, developed or otherwise constructed. This phase often consists of other specific cycles, such as the system development cycle or the acquisition cycle. During the first part of the development/acquisition phase, the organization should define the security and functionality requirements of the system in parallel. In the last part of this phase, the organization should conduct development tests of technical and safety measures/features to ensure that they work as intended before moving on to the implementation and integration phases.	50 to 60	from a few months to a year
Implementation phase	In the implementation phase, the organization configures and commissions the system, tests its functionality, installs or deploys the system, and obtains formal authorization to operate. Design reviews and system testing must be carried out before commissioning to ensure that all required functional and non-functional specifications are met. In addition, if new security measures are added to the application or support system, additional acceptance tests of these security measures should be performed. The results of design reviews and system tests should be fully documented, updated as subsequent reviews or tests are performed, and maintained in the organization's official records.	5 to 10	

Use and maintenance phase	An effective program requires a comprehensive and ongoing understanding of program and system weaknesses. In this phase, systems and products are deployed and operational, improvements and/or modifications to the system are developed, tested, and hardware and/or software is added or replaced. During this phase, the organization should continuously monitor the operation of the system to ensure that it complies with the previously established user requirements and that necessary modifications to the system are implemented. For configuration control and management, it is important to document proposed or actual changes to the system plan. Information systems are typically in a state of constant evolution due to upgrades in hardware, software, and firmware, and possible changes in the system environment.	10 to 15	many years
Phase: Phase: Phase:	In the system lifecycle, the retirement phase refers to the process of persisting (where applicable) and removing system information, hardware, and software. This step is extremely important because during this phase, information, hardware, and software are transferred to another system, archived, discarded, or destroyed. If not properly executed, the deprecation phase may result in unauthorized disclosure of sensitive data. When archiving information, organizations should consider the need and methods for future retrieval. Although electronic information can be stored and retrieved relatively easily, problems arise when the technology used to record it is no longer available because of obsolescence or incompatibility with new technologies. In addition, the organization should consider what measures should be taken to enable future use of encrypted data, e.g. by ensuring long-term and secure storage of cryptographic keys. It is equally important to consider the legal requirements for data retention after the information system has been decommissioned. In the case of public systems18, the system managers should consult the body responsible for storing and archiving public documents. Removing information from a medium, such as a hard drive or tape, is called sanitization. There are four categories of media sanitization: disposal, purification, erasure, and destruction20. Because different ways of sanitization provide different levels of information security, organizations should be guided by information security requirements when choosing the method that best suits their needs.	5 to 10	from a few weeks to a few months

Source: Own study

You may notice that some GISs, such as ArcGIS Living Atlas, may have update and mature support lifecycles that are independent of the software lifecycle. In the case of BIM (Building Information Modeling) related systems, the life cycle can include information management throughout the life cycle of a building, from initial design to decommissioning (What is BIM…). In summary, the life cycle of a GIS can range from a few months to many years, depending on several factors, including the scope of the project, technology, and update processes. If you need more detailed information about a specific GIS, I will be happy to help you with your further search.

GIS project management tools. Many GIS lifecycle management tools help you effectively manage your GIS projects from start to finish. Here are some examples of tools (Table 6) that can be used for this purpose (DevOps tools…; TOP 10 tools DevOps…; DevOps Best Practices; Support DevOps ….; Best DevOps Tools).

Table 6. Examples of tools that can be used to manage GIS projects

Name	Description
Visure Requirements ALM Platform	It is an ALM (Application Lifecycle Management) platform that specializes in requirements management and integrates various ALM processes such as risk management, issue and defect tracking, traceability management, and change management.
IBM Engineering Requirements Management DOORS Next	It's a requirements management tool that helps you manage the application lifecycle by offering features like requirements tracking, change management, and impact analysis.
Jira Software	It is a popular project management tool that can be used to track progress, assign tasks, manage requirements and defects, and support Agile and DevOps processes.
SpiraTeam by Inflectra	It's an end-to-end ALM solution that helps teams manage program requirements, releases, iterations, tasks, defects, and code in a single environment
Siemens Polarion ALM	It's an ALM tool that provides features for requirements management, quality control, release planning, and progress tracking.

Source: Own study

These tools offer a variety of features that can help with various aspects of GIS lifecycle management, from requirements gathering to design and development to implementing and maintaining systems. Choosing the right tool depends on the specific needs of your project and organization.

Good practice tools in the field of GIS systems engineering. DevOps is a set of practices and philosophies that combine software development (DEV) and IT operations (OP) to shorten the systems development lifecycle and ensure the continuous delivery of high-quality software. In the context of GIS systems, DevOps can be applied as follows (Table 7) (DevOps: Who is he…; How are Agile and DevOps related?).

Table 7. DevOps – a set of practices and philosophies

Area	Characteristics
1. Process automation	Automate routine tasks such as testing, data integration, and deployment of updates, allowing you to make changes to your GIS faster and more efficiently.
2. Continuous Integration and Continuous Delivery (CI/CD)	Implementing continuous integration and continuous delivery enables ongoing testing and deployment of changes to GIS systems, which contributes to their stability and reliability.
3. Cross-team collaboration	DevOps emphasizes collaboration between development teams and operations professionals, which is crucial for complex GIS systems where different departments need to collaborate effectively.
4. Monitoring and scaling	Infrastructure management, including monitoring the performance of GIS systems and scaling them according to user needs and system load.
5. Infrastructure management as code	Use code to manage configurations and infrastructure, making it easier to manage and version complex GIS environments.
6. Security	Integrating security practices into the development process, which is especially important for geospatial data that may be sensitive or legally protected.

Source: Own study

Applying DevOps to GIS can contribute to more efficient and flexible product development, enabling faster deployments, fewer errors, and increased system stability. This is especially important in dynamic environments, where rapid adaptation to changing market and customer needs is crucial (DevOps: Who is he…; Best ALM Tools).

Tools supporting GIS design. In the GIS design process, tools of a practical nature are used. DevOps includes many tools of this type that help with the automation of planning processes, configuration management, continuous integration and delivery, as well as monitoring. Table 8 contains some of the most important DevOps tools used in GIS projects.

These tools are crucial for supporting the DevOps lifecycle of GIS projects, from planning and design, through development and testing, to deployment and monitoring. Choosing the right tools depends on the specific needs of your project and organization.

Table 8. DevOps tools for GIS projects

Name	Description
1. Git	A version control system that is the foundation for many DevOps practices, allowing teams to collaborate effectively on code (DevOps tools…).
2. Jenkins	An open-source automation server that helps you automate various stages of the product delivery process, including GIS (TOP 10 tools DevOps…) projects.
3. Meatball	An infrastructure-as-code management tool that automates management, delivers software faster and more securely (DevOps tools…).
4. Chief	An open-source automation and configuration management tool that uses "Cookbooks" to code (TOP 10 tools DevOps…) infrastructure.
5. Ansible	A configuration management tool, known for its simplicity and performance, that takes an infrastructure-as-code approach (DevOps tools…).
6. Docker	A containerization platform that enables you to package, distribute, and manage applications in isolated environments (DevOps tools…).
7.Kubernetes	A system for automatically deploying, scaling, and managing containerized applications, which is especially useful in large, distributed environments (TOP 10 tools DevOps…).
8. Bamboo	Atlassian's CI/CD server solution that integrates with other tools and streamlines processes in GIS projects (Best DevOps Tools).
9. Nagios	A system, network, and infrastructure monitoring tool that tracks asset performance and availability in real time.
10. Mural i Miro	Tools to support the discovery phase of DevOps, enabling teams to gather ideas and conduct research (Best DevOps Tools).

Source: Own study

AI tools used in the GIS architecture design process. AI tools are increasingly being used in the GIS architecture design process, offering a wide range of capabilities, from concept generation to optimization and analysis. The use of AI in GIS architecture design can lead to unexpected design outcomes, broadening the designer's perspective and enriching the design process. By integrating AI tools, designers can work with greater precision and awareness, optimizing resources and highlighting critical decision-making processes (Extract Features Using AI Models…). There are ready-made AI tools designed for GIS systems. Table 9 provides some examples.

Table 9. Examples of AI tools

Name	Description
1. GeoAI toolbox	in ArcGIS Pro: Includes tools for using and training AI models that work with geospatial and tabular data. These tools use modern machine learning and deep learning techniques, integrating them with GIS (An overview of the GeoAI toolbox…).
2. Extract Features Using AI Models (GeoAI)	It allows you to run one or more pre-trained deep learning models on an input raster to extract features and automate post-processing of inference results (Extract Features Using AI Models…)(Platforms for Making Deep Learning Easier …).
3. Ready-to-use deep learning models	Esri provides ready-to-use geospatial AI models in ArcGIS Living Atlas of the World (Ready-to-Use…).
4. Facial analysis and AI	It enables faster answers in images with advanced image analysis at scale, including feature extraction using geospatial artificial intelligence (GeoAI), change detection (Image Analysis and AI).

Source: Own study

These AI tools for GIS can significantly improve the processes of geospatial data analysis, feature extraction automation, as well as prediction and estimation in various GIS applications. In addition, there are AI tools for GIS available as open-source software. Here are some examples (Table 10).

Table 10. List of AI GIS tools as open-source software

Name	Description
1. PDAL	The Point Data Abstraction Library (PDAL) is used to process point data and supports integration with machine learning (Open Source GIS…).
2. Open3D	It is an open-source toolkit for working with 3D data, which can be used in conjunction with machine learning for spatial 3D data (Open Source GIS…).
3. PyTorch and TensorFlow	This is a generally available framework for machine learning and deep learning that can be applied to geospatial data analysis (Open Source GIS…).
4. GRASS GIS	It is a geographic information system (GIS) that also includes tools for spatial analysis and integration with various tools, including machine learning (GeoAI: Machine Learning…).
5. GeoTools, Geoserve, gvSIG, OpenMap	These are examples of popular open-source GIS tools that offer a variety of features, including AI-related capabilities (An overview of the GeoAI toolbox…).

Source: Own study

These tools and libraries allow you to work with geospatial data and use AI techniques to analyze, model, and visualize GIS data (How Artificial Intelligence is Improving ...).

Assessment of the impact of AI technology on the basic parameters of the GIS project. Obtaining quantitative measures or performance indicators reflecting the impact of the use of AI technology in the life cycle of a GIS project is possible by using the System Dynamics method and the simulation model of the Earned Value (EV) technique. The system dynamics method uses two main structures in the process of modeling and designing GIS architecture:

- cause-and-effect loops based on feedback loops occurring in the system,
- inventory and flows – variables showing the state of the system at a selected moment.

Earned Value (EV) is a project management technique that measures results and progress in the context of planned scope, time (schedule), and cost (budget) at a selected point in time (Fig. 6).

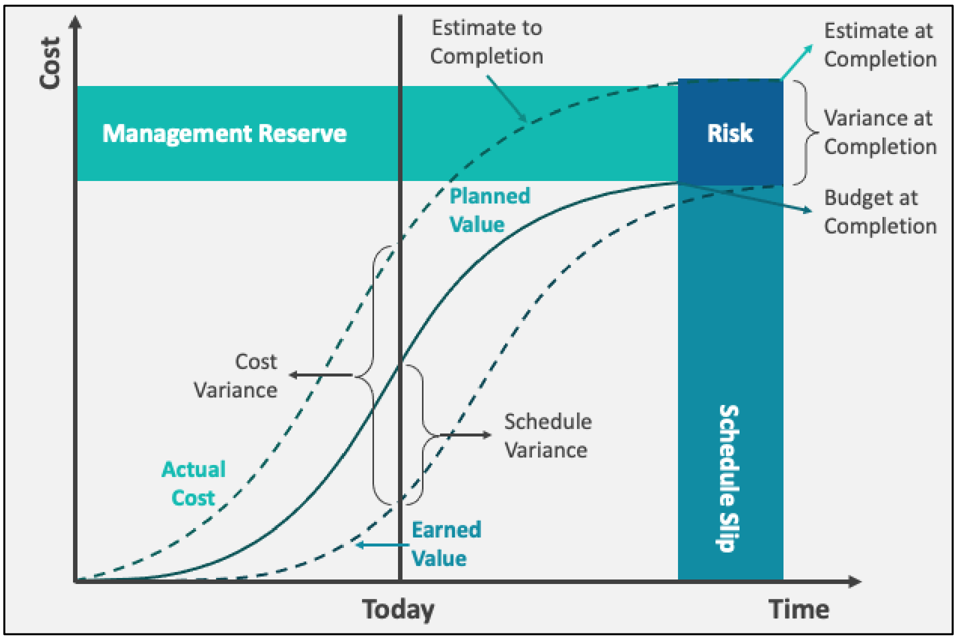

Fig. 6. Illustration of the Earned Value (EV) method
Source: Own study

The simulation model built according to the assumptions of the Earned Value method using the Vensim® simulation environment is shown in Fig. 7.

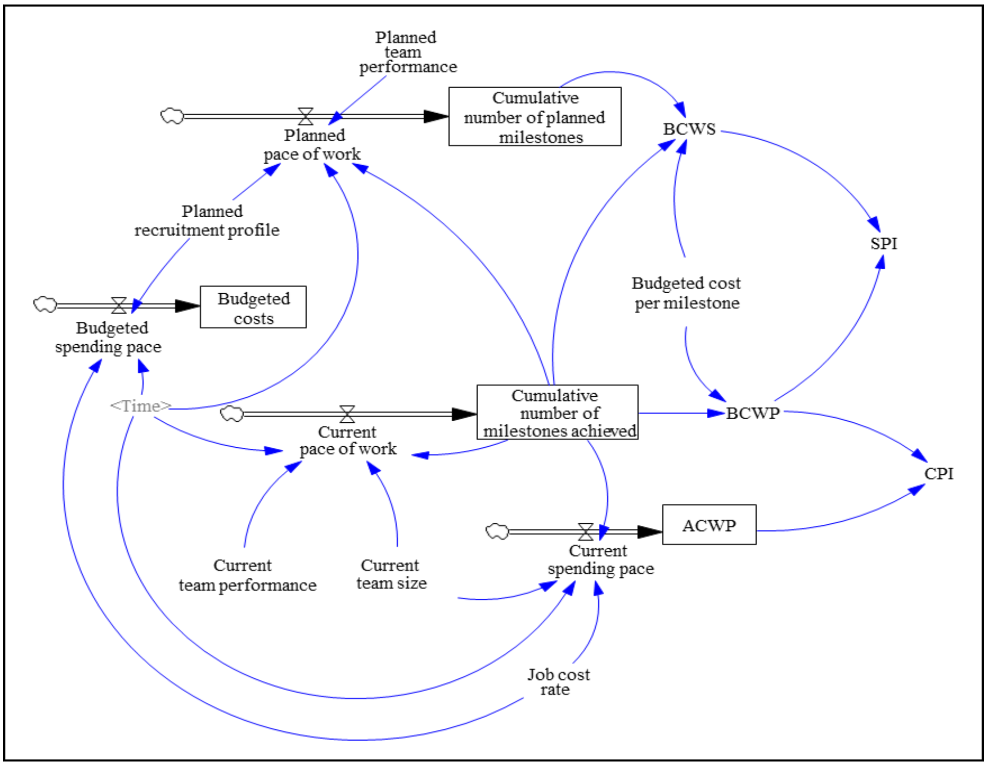

Fig. 7. Earned Value simulation model
Source: Own study

Based on the constructed model, simulation experiments were carried out, the results of which were then used as input material for the assessment of the basic parameters of the GIS project. Figure 8 illustrates the model that was used to determine the basic indicators of the EV method.

The indicators allow you to assess the condition of the GIS project in the context of compliance of the pace of work and budget consumption with the assumed plan for the following ways/variants of conducting the GIS project:

I. GIS lifecycle management using GIS and DevOps tools for project management,
II. GIS lifecycle management with an additional suite of AI tools designed for GIS (GeoAI).

Table 11 contains calculations relating to the following PV (Planned Value), EV (Earned Value) and AC (Actual Cost) indicators for both variants at the time of 1/3 of the project duration.

Analysis of the dynamics of changes in EV and AC indicators compared to PV allows to forecast the date of the end of the project and the amount of costs of the entire project. While the benefits of using AI in GIS projects are undeniable, organizations need to have a comprehensive understanding of the expenses involved to avoid unpleasant surprises. ("What are the Risks and Benefits of Artificial Intelligence (AI) in ...") As of today, the "profits" from the introduction of AI technology to the GIS project, expressed in percentage increments, are 2–8% for small and medium-sized companies, 5–25% for large companies.

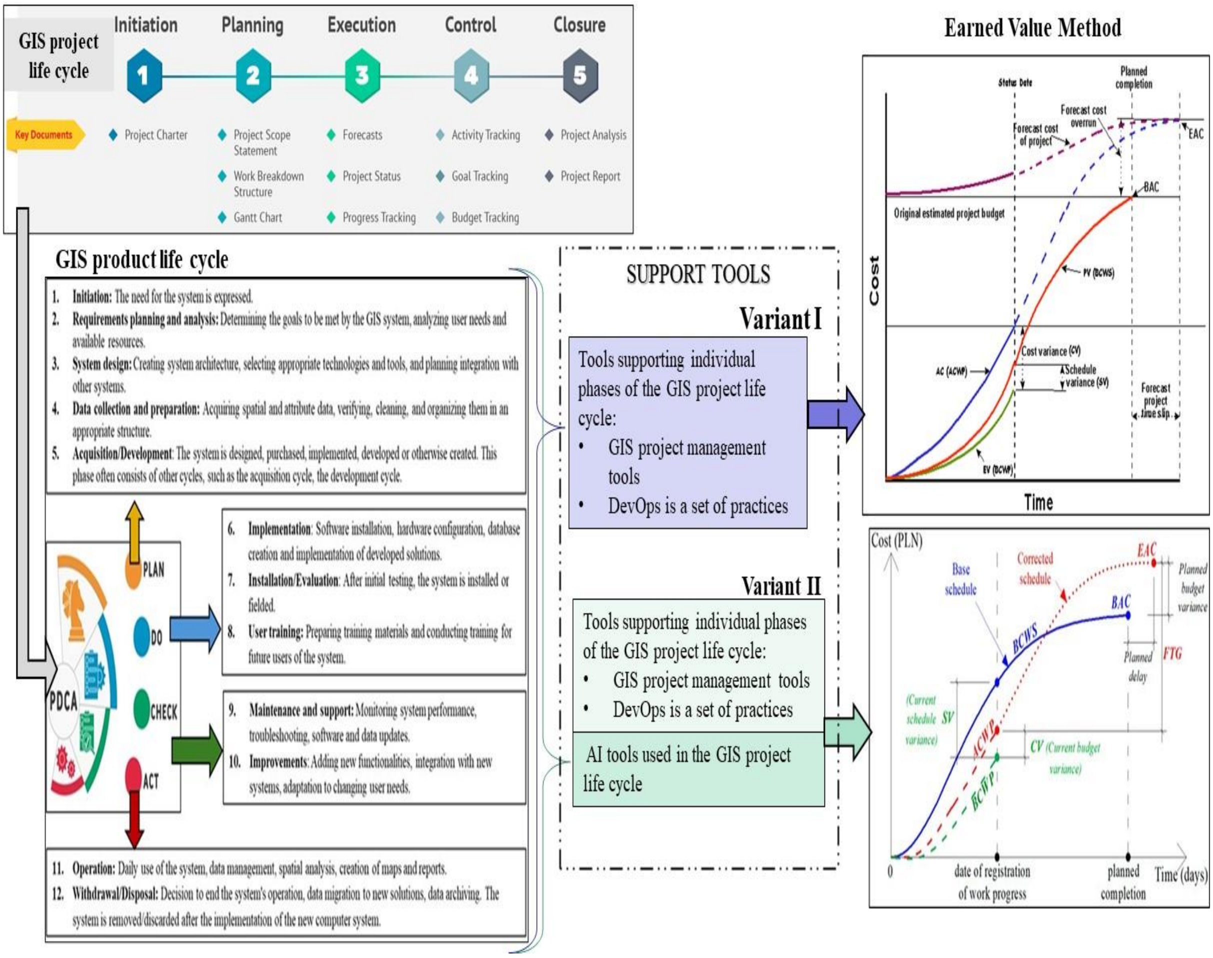

Fig. 8. A model used to determine the basic indicators of the EV method
Source: Own study

Table 11. Examples of calculations of PV, EV, AC indicators as well as the costs and duration of a GIS project

Indicator name	Indicator value [$]	
	Variant I	Variant II
1. GIS Project Duration – The life cycle of a GIS system can range from a few months to many years, depending on several factors, including the scope of the project, technology, and update processes.	40 weeks	30 weeks
2. Cost (budget) of the GIS-BAC project	80.000	65.000
3. PV, also known as **BCWS (Budgeted Cost of Work Scheduled),** is the value of the planned scope delivered from the start of the project to the day of the inspection. We calculate it based on the planned schedule and costs. If we have specific tasks and their projected costs, we can calculate PV as the sum of costs planned to be performed up to a given point in the project.	25.500	18.000

4. EV, or **BCWP (Budgeted Cost of Work Performed),** is the value of the scope delivered from the beginning of the project to the date of the audit but calculated in the rates adopted in the project budget. We calculate it based on the actual progress of work. If we have information about the actual tasks performed and their costs, we can calculate the EV as the sum of the costs of the work done up to a given point in the project.	18.500	18.000
5. AC, also known as **ACWP (Actual Cost of Work Performed),** is information about the actual cost of a project consumed from the beginning to the day of the inspection. We calculate it based on actual spending. If we have data on the actual costs incurred, we can calculate AC as the sum of these costs up to a given point in the project.	35.750	17.500
6. SPI (Schedule Performance Index): SPI = \frac{EV}{PV}SPI=PV/EV	1.377	1.000
7. SV (Schedule Variance): SV = EV – PV	7.000	0.000
8. CPI (Cost Performance Index): CPI = \frac{EV}{AC} CPI=AC/EV	1.401	0.998
9. CV (Cost Variance): CV = EV – AC	17.250	500

Source: Own study

Conclusion

Overall, the use of AI in a GIS project can streamline and increase the efficiency of the GIS project lifecycle by significantly improving the basic parameters of the project:

1) Time: AI can help automate certain tasks and processes, reducing the time it takes for manual work. For example, AI can help automate the GIS architecture design process. This can speed up the deployment process and allow for more efficient resource allocation.
2) Cost: While the initial investment in AI technologies and tools can increase upfront costs, it can potentially lead to long-term savings. AI can help streamline processes, reduce human error, and improve efficiency, resulting in cost savings over time. However, it is important to carefully evaluate the cost-benefit analysis before implementing AI solutions.
3) Quality: AI can improve the quality of your deployment by providing more accurate and consistent results. For example, AI-powered tools can help you identify vulnerabilities or anomalies more effectively than manual methods. This can lead to better risk management and a better overall cybersecurity posture.

Geographic Information Systems (GIS) and AI (Artificial Intelligence) are often used together to gain deeper insights and better process spatial data and reduce the time and cost of a GIS project. GeoAI, or geospatial artificial intelligence, is the integration of AI techniques and technologies with GIS data and analysis.

According to the IndustryARC report (Artificial Intelligence in Geospatial Analysis…), the market for artificial intelligence for geospatial analytics is expected to grow to $172 million by 2026, highlighting the huge potential and importance of this trend.

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