

Geographic Information Systems Within Enterprise Resource Planning Systems

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Geographic information systems (GIS) have become very important tools in many areas in recent years, including resource management and utilization in many industries. GISs are sometimes referred to as computer tools, but sometimes they are defined as information systems consisting of software and database.

geographic information systems (GIS)

enterprise resource planning (ERP)

GIS and ERP integration

GIS acceptance

technology acceptance model (TAM)

1. Introduction

There are two types of geodata—raster geodata and vector data ^[1]. Raster data can be distinguished by the content—, i.e., imagery, height models, land use classes, population data, temperature, etc. Vector data (also referred to as feature data) represent individual objects that are modeled as geometries of a certain location and depend on the geometric dimension of the objects modeled ^[2]. A feature class can consist of points, lines, or polygons. For geodata use, special formats support the delivery of spatially and/or thematically limited extracts of data in a dataset. Among others, raster analysis in Geographical information systems (GIS) comprises terrain analysis, hydrologic analysis, surface modeling, surface interpolation, multi-criteria analysis, image classification, etc. ^[2]. Their functionality to capture, analyze, visualize, and model territories with large volumes of spatial data open many possibilities for their use in different areas. Besides environmental issues (e.g., weather forecasting climatic change ^[3], flood modeling ^[4]), there are also several areas of economic issues (e.g., cost–distance analysis and optimal routes, location–allocation analysis, land suitability modeling, etc.) (for example ^{[5][6][7][8]}). A special area of GIS functionality is spatial statistics, in which exploratory techniques for describing and modeling spatial distributions, patterns, processes, and relationships are used ^[9]. There are three options for spatial visualization ^[10]. The most elementary options for spatial visualization are choropleth maps. The intensity of the phenomenon is expressed using a color fill or raster/pattern in a polygon, converted to a unit of the surface of the observed territory. The second option for spatial visualization is cartograms, and thematic maps, which enable the visualization of variables such as population, travel time, GNP, etc. The third option for spatial visualization is proportional symbols, which use points or lines to visualize the distinct variable. GIS functionality was traditionally used for urban planning, utility management, ecosystems modeling, transportation, and infrastructure planning ^{[11][12]}. Besides these, many areas have recently emerged, especially used in business processes of companies in different industries, i.e., marketing, facilities management, taxation issues, real estate business, etc. (for example, ^{[13][14][15]}).

Recently GIS is often used in companies by users in different business areas where employees already use enterprise business information systems such as project management information systems, customer relationship management systems (CRM), enterprise resource planning systems (ERP), etc. In one of the earliest articles [\[16\]](#) referring to the use and integration of GIS in information systems supporting business activity, the computer-supported project management in the Port Authority in New York/New Jersey was studied. It analyzed and discussed the importance of computer-supported project management, including GIS integrated with project management information systems and enterprise information systems. It was argued that the integration of mentioned information systems provides necessary information for project managers to manage their tasks more efficiently and effectively. Integrating GIS with more complex Enterprise information systems such as Enterprise resource planning systems (ERP) opens additional dimensions while, typically, ERP systems are used to support the entire company, not only a project or distinct business area. ERP systems are information systems that an organization can use to manage all business data and make them available for employees in all business areas for their daily business activities [\[17\]](#). Until recently, GIS systems remain relatively isolated technology, as mentioned above, to capture, store, check and display data related to geographical positions. Therefore, existing enterprise information systems architectures often separate ERP systems and GIS [\[18\]](#), and in many cases, business processes and spatial processes are perceived as distinct processes [\[19\]](#). As most business data have a spatial or geographic dimension that can be georeferenced for visualization on a GIS map, their interpretation through a spreadsheet or similar method is not adequate [\[20\]](#). This integration can bring many advantages by integrating ERP systems functionality, especially their workflow management features, with GIS for location-based information management. An example of such integration is studied in an article dealing with the necessity of integrating ERP systems and GIS in tourism [\[21\]](#).

The usefulness of information systems is not determined only by their functionality, but also by the level of their acceptance by users. To get more benefits from information systems and increase the efficiency and effectiveness of information system use, organizations should be aware of the factors that impact employee acceptance [\[22\]](#). The Technology Acceptance Model (TAM) is, among the models known, the model which is used most often for researching the behavioral intention of employees and their actual use of information systems in companies. It is often argued that TAM improves understanding of how influences on actual use of information systems could improve information systems used [\[23\]](#). The literature review has shown that several studies on users' adoption of information systems in past years, and many of them focused on ERP systems, where research has been based on TAM, have been published. A review also showed that almost all studies have focused on ERP systems' business modules and not on other tools and modules that enhance business modules. Very few studies have researched the acceptance of GIS by users. Studies researching the usefulness of GIS in connection with ERP systems where GIS is integrated with ERP business modules are even more seldom.

2. Integration of GIS and ERP Systems

GIS are computer tools for creating and visualizing digital maps [\[24\]](#). NCGIA (National Center for Geographic Information and Analysis) defines GIS as a system that supports and enables design, modeling, analysis, and

visualization of georeferenced data to use in solving problems regarding planning and management of different resources [25]. GIS enables the representation and integration of spatial information. The data referenced in GIS tools and presented in maps may relate to natural sciences such as biological, physical, chemical domains as well as other sciences such as social, environmental, economic, or any other properties of the earth's surface. GIS tools support mapping, querying, modeling, and analyzing, with the use of large quantities of diverse data, using a single database (for example [2][26]). GIS strength and popularity are thus connected with its ability to combine large quantities of environmental information and its functionality offered by GIS tools, which enable the research of diverse data [27].

The researchers conducted a bibliometric analysis to get insights into research in this area. The overview of bibliographic units indexed in Scopus was obtained on 12 November 2021. Scopus is Elsevier's database of citations and abstracts of bibliographic publications, which was introduced in 2004 to encourage experts and institutions in research work and the use of the results of scientific findings. It is a highly regarded collection of abstracts and citations of research results published in peer-reviewed publications, especially in scientific journals [28].

Based on keywords »GIS« and »Enterprise Resource Planning«, the search revealed 47 bibliographic units, as presented by **Figure 1**.

Documents by year

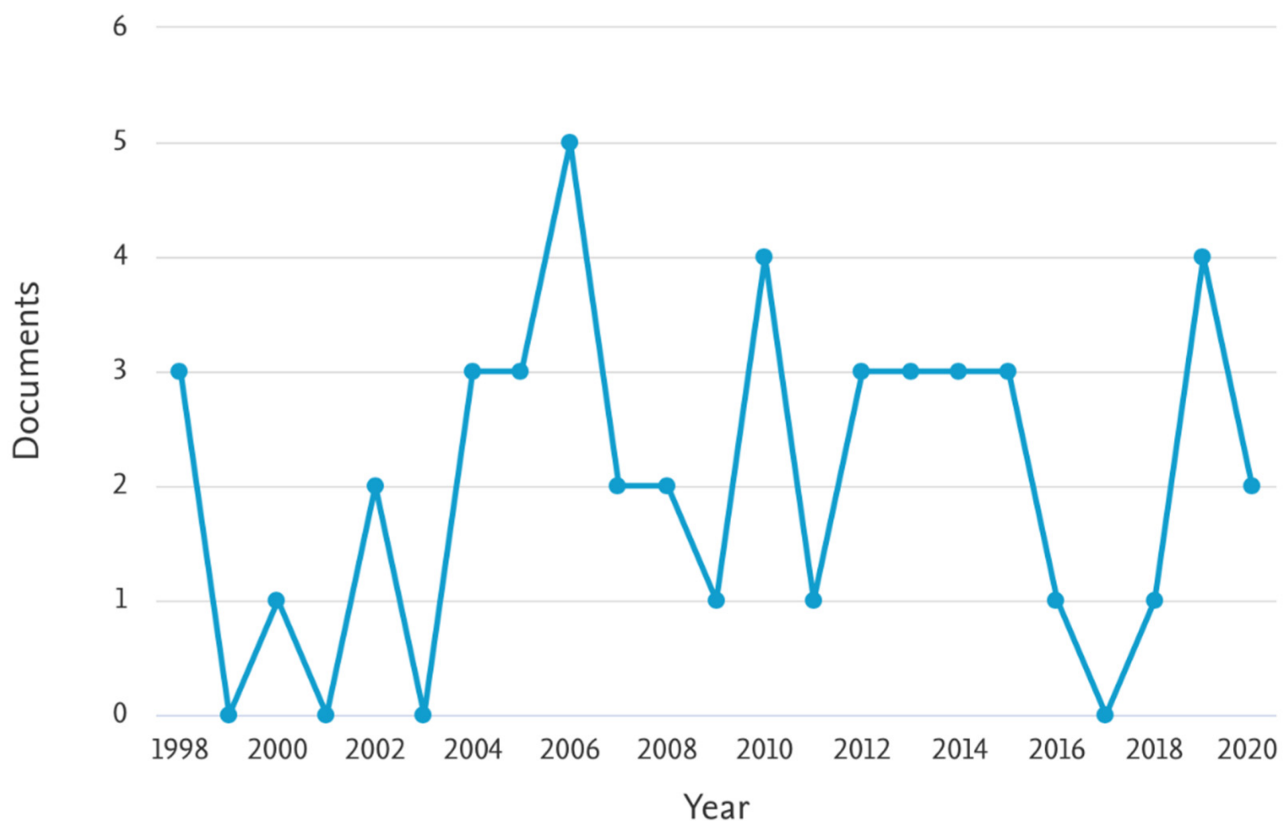


Figure 1. A number of bibliographic units, indexed in Scopus, on 2 November 2021, keywords »GIS« and »Enterprise Resource Planning«.

The number of bibliographic units was detected from 1998 onwards, and the research opus fluctuated over the years. If the researchers look at the content, there is also a visible transition from a greater emphasis on the GIS system to systems where a high level of connection and interaction between the two systems, GIS, and ERP, can be observed. Even before 1998, the research attempts to connect GIS with the planning in enterprises and, generally, with information systems to support decision making exist.

Early research studies in this area have focused on managing resources in different business areas. In one of the earliest research attempts, research focused on the development of the GIS in Australia, with the purpose of developing tools providing decision support for resource planning and effective utilization of GIS [29]. Another example focusing on spatial economics is the article of Walford [30]. It deals with the distribution of tourist farms in the UK, which is an important part of the rural tourism system. The geographical characteristics of the tourist farms' environment can significantly contribute to the diversification of tourist farms and to the identification of individual accommodation. The information system, which connects rural tourist accommodation with the exceptional characteristics of the location, such as natural sights, cultural heritage sites, and the like, enables the diversification of the characteristics of individual accommodation. At the same time, it allows the analysis of patterns of influence of micro-location and characteristics of adjacent areas on tourist accommodation, and thus on the planning of further development of areas and rural tourism.

A highly cited article by Li et al. [31] that directly connects GIS and ERP systems in companies is dealing with construction waste management. The utilization of a global positioning system (GPS) and GIS technology to reduce construction waste, with barcoding information systems for the management of construction materials and equipment, is proving to be very effective in reducing on-site waste. Similarly, a highly cited article from the oil industry emphasizes the importance of a high degree of integration of individual systems in comprehensive information systems. Research in this area for a diversified oil company supplying oil derivatives from distribution centers to many customers [32] found that it was possible to successfully link a supply chain management application with GIS and ERP systems to gain an innovative decision support tool.

In recent research, an even greater emphasis is on information systems that utilize GIS and incorporate it with ERP systems, often focusing on specific characteristics of the organization. The recent research [33] focuses on ERP systems for water management that uses GIS to develop an efficient water management system targeting the general objectives of water security. Smart water management systems consist of several strategic methods and tools, and this research confirms that such a connection can help build an efficient water management system, thus reducing the threat to water resources, consequently leading to water loss and higher production and distribution costs.

Similarly, the advantages of incorporating GIS into ERP systems are highlighted in the research of Morales et al. [34]. This research focuses on an information system of a platform that would provide process management in

agriculture, specifically in Spain, to produce wine with a protected geographical indication. This type of platform is based on the principles of ERP systems and geolocation information from land related to the protected geographical indication. Research has confirmed that the benefits of using such information systems are multifaceted. On the one hand, the platform provided access to agricultural data and geolocated information in real-time, and on the other hand, it provides management tools to the individual or organization, the holder of agricultural activity, which enables the future development of agricultural systems.

When analyzing the integration of GIS and ERP systems in organizations, the advantages of such integration are particularly emphasized [35]. Through integration, the employee in the organization who use systems can visualize ERP business data inside the GIS tools and can get direct access to the GIS functionality provided by tools inside the ERP system [36]. A user of integrated systems can get support on a higher level while he/she is empowered to make decisions by visualizing the information from both systems simultaneously on the workstation [37]. As support is provided on an advanced level, switching between systems is not needed anymore. Abou-Ghanem and Arfay [20] pointed out that integrating GIS into ERP systems offers features that fall into the three categories:

- Adding geo attributes for business decisions by linking business data with geo data.
- Integrating business functionality from ERP system with geo functionality from GIS provides mixed functionality, which is accessible to all software components.
- Combining business and spatial information and functionality to all levels of users.

GIS and ERP integration enables new business transaction scenarios or improves the execution of existing business transactions that use the combined functionality of both systems. GIS and ERP integration can utilize an ERP-centric approach, GIS-centric approach, and composite ERP/GIS approach [37][38]. In the GIS-centric approach, the map is the main user interface, and business data from ERP is accessed from the map, so the user typically selects features and retrieves business ERP data or updates it using the ERP transaction module. The ERP-centric approach, on the other hand, embeds a map within the ERP user interface. The map, in this case, has less GIS functions and available tools than in a GIS-centric approach, but still allows event-based business retrieval of ERP data. The composite ERP/GIS approach uses services of both GIS and ERP systems, and the user interface is designed according to the functionality of the business task, with the map providing a central or supporting role.

Integrated GIS and ERP systems support business processes and provide functionalities such as [39]:

- Decisions regarding product distribution and management of transport costs by mapping relationships between customers and plant/storage locations.
- Decisions where to define optimal location of new production facilities according to selected criteria.
- Managing supply chain and/or distribution from a geographic viewpoint.

- Managing service activities by analysis of response time by regions.
- Decisions regarding customers by analyzing their habits from the viewpoints of attributes such as preference for a product and visualizing them on the map or mixing them with demographic data for better marketing and sales.

3. Acceptance of Information Systems by Users

The successful use of information systems and information technology depends not only on how successful the implementation has been in organizations, but above all on its efficient and successful use by users after implementation. Researchers use several theoretical research models to study the acceptance of information systems and information technology. The most popular models used are: the Theory of Diffusion of Innovation (DIT; [40]), the Theory of Task-Technology (TTF; [41]), the Theory of Planned Behavior (TPB; [42]), the Theory of Reasoned Action (TRA; [43]), Decomposed Theory of Planned Behavior [44], the Technology Acceptance Model (TAM; [45][46]) and extensions TAM 2 [47], TAM 3 [48], Unified Theory of Acceptance and Use of Technology (UTAUT; [49]), etc., see [50][51].

To explore the end-user acceptance of information systems, TAM and its latest versions have proven to be the most promising among the above-mentioned research models [23][52][53][54][55][56][57][58]. The power of the TAM is confirmed by many studies that highlight its wide applicability to various technologies [59]. In TAM, two beliefs are initially important for the acceptability of systems and technology [45]. These beliefs are perceived usefulness (PUS) and perceived ease of use (PEU). TAM determined perceived usefulness (PUS) is the point to which an information system user believes that the work with a particular information system would improve its performance, while perceived ease of use (PEU) is defined as the point to which the information system user considers that the work with the certain information system will not require additional work [45]. These two beliefs further positively influence the information system user's attitude about the use of particular information systems (ATU), which in turn affects the information system user's behavioral intention regarding the work with the particular information systems (BIU). The behavioral intention of using a particular information system (BIU) is further positively linked to its real use. In the model, TAM has also highlighted the relationship between perceived ease of use (PEU) and perceived usefulness (PUS), as the work saved for the reason that improved perceived ease of use can be reallocated, allowing information system users to do more work at the same time and with the same effort. Perceived usefulness (PUS) is also positively related to the behavioral intention of using a particular information system (BIU) because if users perceive greater usability of a particular information system, they will be more likely to intend to use that information system [46].

Basic TAM and its extended versions have been used to research the acceptability of different information systems (e.g., [59][60][61]). Although TAM is used in a variety of different information systems, TAM additions and/or modifications are required in the analysis of specific information technology [57]. Marangunić and Granić [59], based on a comprehensive literature review (85 scientific publications), pointed out that despite progress in discovering new factors that have a significant impact on the basic variables of TAM, there are many unexplored parts of the

application of the model that can contribute to its predictive power. They added that they could highlight four main ways of TAM implementations for research in the future: moderating the role of various variables, including additional variables in TAM, researching actual use, and exploring the target group of older adults.

Additionally, in the area of ERP systems, some studies have been done on the acceptance of ERP systems by companies' employees [23][53][54][58][61][62][63][64][65][66][67][68][69][70][71][72]. An evaluation of previous ERP research related to TAM shows that various research has explored ERP system acceptance [73][74] where researchers have explored different views of the ERP use, usually focusing on a limited number of external factors that can involve the ERP acceptance at different stages of the ERP system life cycle [23][55][56][57][58][65][67][68][75][76][77][78][79][80][81][82].

Most ERP acceptability studies focus on the system's acceptance by companies' employees. Research studies designed to analyze the factors influencing students to adopt an ERP system are rare. One of the earliest research projects conducted among students regarding the ERP system analyzed students' readiness to change (gender, computational self-efficacy, and perceived ERP system benefits) regarding the purpose of behavior intention to work with ERP system (BIU) in the year 2006 [83]. The research conducted in 2007 focused on a case study at a medium-sized university, where the relationship between training, satisfaction, and perceived usefulness (PUS), perceived ease of use (PEU), efficiency, and effectiveness of using the ERP system was studied [77]. Another research conducted in 2009 explored the following determinants of computational self-efficacy in multimedia use software: students' cognitive engagement, computational fear, organizational support, as well as prior experience [84]. Sternal Zabukovšek et al. [69][70][85][86][87] examined the economics and business students' acceptance of ERP systems and the impact of external factors that shape their goals to utilize this expertise in their upcoming professional careers. The Sternal Zabukovšek et al. extended version of the TAM-based research model has been built up from three detected second order (multidimensional) external factors. Research results showed that some external factors of these three second order (multidimensional) factors were a vital part in determining students' attitude towards the adoption of ERP systems.

When researching acceptance of GIS using TAM, the researchers found that although there are studies that report about the adoption of GIS by users, they do not relate to GIS integration with ERP systems, but merely to the acceptance of GIS as such. The research reports are found in various areas, such as studying readiness to use GIS in the private health system for better management in the perspective of the COVID-19 pandemic [88] or in natural disaster management [89], if the researchers mention only two of the most recent studies.

GIS integrated with ERP system and the acceptance of such system by users was the focus of single research, found in Scopus (as of 23 November 2021), where the acceptance was assessed by the acceptance test (not TAM modeling) [90]. The research highlights the importance of GIS in the management of maritime freight terminals, which were not yet integrated with ERP systems at the time of the research. Therefore, the researchers proposed the inclusion of a GIS module within the ERP system and presented the integrated system possibilities. Acceptance rates were reported to be high in Indonesian sea freight ports.

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