Digital Transformation of Resource Management of Territorial Communities Based on the Cloud ERP System in the Concept of Industry 4.0

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ABSTRACT [1]

The aim of this study is to explore the potential for creating a unified digital information space using a modern ERP system to manage all processes and resources of territorial communities, which are categorized as non-industrial enterprises. This research is conducted in the context of building a modern landscape of Industry 4.0 technologies, which are considered to be the future of industrialization. The practical case of Ukraine is used to illustrate the typical problems associated with the uncoordinated use of different types of software in the management of enterprises and organizations operating in territorial communities. Furthermore, the advantages of switching to a new ERP platform are discussed. The benefits of deploying the system's multi-tier architecture in the cloud and implementing a corporate model for parallel management of individual divisions and organizations are also highlighted.

Keywords: Industry 4.0, Cloud ERP, Community 4.0, Digital Technologies, Project Management.

1. INTRODUCTION

The 21st century has witnessed the emergence of Industry 4.0, which is characterized by the dominance of knowledge and digital data. In this era, the development of new technologies for the automation of production processes requires a greater emphasis on knowledge and skills regarding learning. The human-machine (H2M) relations are also shifting towards a reverse type of M2H, where machines interact without human participation (M2M) [1]. Despite the diversity of the technologies involved in Industry 4.0, four key technologies are essential: smart automation using artificial intelligence (AI) and the Industrial Internet of Things (IIoT), analytics and processing of big data (Big Data), and decentralization of management.

The reorganization of traditional hierarchical automation systems into self-organizing cyber-physical production systems (CPS) is a significant consequence of Industry 4.0 for all types of industrial production systems. This system allows for flexible mass production to order [2]. The "Industry 4.0" project was one of the ten "Future Projects" identified by the German government as part of the High-Tech Strategy - 2020. Countries that adopt a similar

strategy will have a significant advantage in maintaining their competitiveness in world markets, not only in industrial production but also in all other areas.

In the pursuit of European integration, Ukraine has made significant strides toward implementing Industry 4.0 technologies, leveraging its robust scientific, intellectual, and educational capabilities. However, progress across industries and other spheres of activity has been inconsistent. Industry and engineering culture in Ukraine at the start of the 21st century can be broadly classified as being at the 2.0 or 3.0 level, depending on the sector. While metallurgical plants and enterprises in the aerospace industry are better positioned for digital transformation due to their export-oriented nature and global competitiveness, other industries such as power engineering lag significantly behind in terms of automation. The Association of Industrial Enterprises of Ukraine (APPAU), established as a funding and strategic development entity for Industry 4.0, has grown into a large expert community owing to the opening of Industry 4.0 centers in the country's leading universities [3]. Given the varying levels of readiness across industries, these centers can help drive the Industry 4.0 movement in Ukraine by providing the necessary resources and expertise.

In contrast to well-automated industries and businesses, many state institutions and organizations, particularly local self-government in territorial communities, face challenges in processing large volumes of data and information. They require digitalization of operational activities, analytics, and decision-making support. The reform of the state administration system and the emergence of territorial communities is a key pro-European reform that is currently underway. With the support of international organizations and the Ministry of Digital Transformation, the Community 4.0 program was launched in Ukraine. The goal is the implementation of digital projects to ensure sustainability, attractiveness for investments, and new concepts. This paper explores the possibilities of creating a unified digital information space on a modern cloud Enterprise Resource Planning (ERP) system to improve the management of all subjects in the territorial community and facilitate the transition to the Industry 4.0 technology landscape. We present a case study on the preparation of a pilot project for local self-government bodies in Ukraine, and discuss the selection and implementation of ERP modules with further prospects for scaling and integration with other systems and technologies.

2. AUTOMATION ON THE ERP PLATFORM AS A CONDITION FOR THE TRANSITION TO INDUSTRY 4.0

At the beginning of the Industry 4.0 era, the focus was solely on industrial production, but the paradigm has since expanded to include other areas of human activity. The paper [4] illustrates the convergence of 12 revolutionary technologies, including 3D printing, artificial intelligence,

augmented reality, big data, blockchain, cloud computing, drones, the Internet of Things, nanotechnology, robotics, modeling, and synthetic biology in various sectors such as agriculture (Agriculture 4.0), healthcare (Healthcare 4.0), logistics (Logistics 4.0), energy (Energy 4.0), and elements of new educational technologies (Education 4.0). Sectors of the economy that encompass automated production, energy efficiency, and enhanced manufacturability will be transformed with new models of the value chain. Global megatrends such as globalization, urbanization, demographic changes, and energy transformation are factors that are driving the technological impulse to create innovative solutions in today's world.

In recent years, the development of Industry 4.0 technologies has expanded beyond the field of industrial production. This expansion includes agriculture (Agriculture 4.0), healthcare (Healthcare 4.0), logistics (Logistics 4.0), energy (Energy 4.0), and elements of new educational technologies (Education 4.0). However, many countries and certain industries still lack development of the previous level of Industry 3.0 technologies, even in developed countries, leading to a gap in competitiveness and opportunities [5]. Enterprises that have started digital transformation create pressure on others to keep up, but this presents risks related to security, personnel competence, data retention, and analytics [6]. The role of powerful ERP systems in processing new types of data, globalization of production, and decentralization of management remain debatable. ERP software will have to solve new tasks, such as data correlation and managing larger and more complex volumes of data [7]. Experts believe that ERP software will be directly related to the control of the management system at the production level and will support Industry 4.0 technologies.

The authors of the work [8] have substantiated the main aspects of creating information systems for the management of production processes for agricultural enterprises and the role of ERP systems in processing big data. The leading role of universities in training modern specialists capable of mastering new IT technologies and e-competencies is shown in [9-10]. Therefore, in this work, the broader application of modern ERP class systems is considered a necessary element of the strategy to achieve the level of technology and culture 4.0 for non-manufacturing companies and organizations. It is important to note that Industry 4.0 is an evolution and continuation of Industry 3.0, and their connection and imitation are important. One cannot "jump" over Industry 3.0, which has not been fully achieved in both industrial and service industries. Industry 4.0 also has great potential to improve the efficiency of businesses and organizations and help restore the natural environment through better asset management, potentially even reversing all the damage caused by previous industrial revolutions.

An ERP-class information system (IS) is a sophisticated software product comprising interrelated technical means, procedures, and personnel that facilitate the storage, processing, and transmission of information while

addressing specific tasks. The object of management in this context is information processes, which are typical across enterprises and organizations of various spheres of activity. As a result, it is possible to achieve a high level of universality of work methods across various systems. Several independent sources have compared modern ERP systems [11-12] and found that they have a standardized composition. ERP systems, which have undergone continuous improvement over time, have a modular structure, with modules working as separate components, and should be easily combined when interacting with the database (Figure 1).
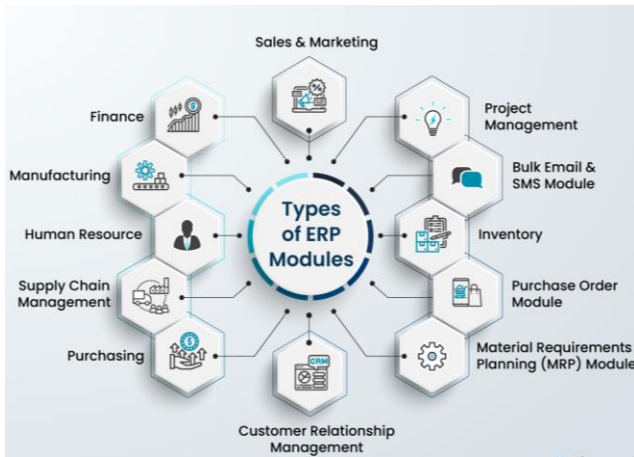

Figure 1. Module's types in a modern ERP system [13]

Most ERP solutions are adaptable and scalable according to the company's needs, which helps to prepare for any situations in business processes or changes in the market and respond promptly to them.

The uniqueness of ERP technologies lies in their ability to serve as universal software capable of integrating any business process. Combined with processes, systems, and data, ERP systems provide the analytics, acceleration, and adaptability needed to optimize business processes. ERP systems can increase the efficiency of organizations in three ways [13]:

1) Increasing productivity: ERP-based solutions provide analytics that helps to make informed decisions and suggests directions for further improvements in operational efficiency.

2) Accelerating operational decisions: Based on unified data and processes, the visibility and agility of employees increase, helping them to take action faster and achieve greater results.

3) Business flexibility: Most ERP solutions are adapted and scaled according to needs and provide prompt responses to risks and changes in business processes.

In summary, ERP systems are universal software that can integrate any business process. They are adaptable and scalable, and their use can lead to increased productivity, accelerated operational decisions, and business flexibility. The Enterprise Resource Planning system is a complex software product that comprises a set of technical means, methods, procedures, and personnel interconnected to perform the storage, processing, and transmission of information for solving specific tasks. The information processes are the objects of management, some of which are typical in various enterprises and organizations, making it possible to achieve a high level of universality in work methods across different systems. The adaptability and scalability of most ERP solutions allow organizations to prepare in advance for any situation in business processes or changes in the market, as well as to respond promptly to them.

The division of ERP into subsystems provides several benefits, including the consideration of production needs during the development and modernization of the IS, the phasing of implementation, and the ease of operation of such IS due to the specialization of employees in the subject area for which separate modules have been developed. Organizations must carefully weigh their options for implementing the system, as the ideal strategy for phasing depends on several factors such as the speed of adaptation of the new ERP, types of risks and their consequences, willingness to invest, etc.

According to the international analytical company Panorama Consulting Group (PCG), as of the end of 2022, the majority of ERP users (64.4%) chose the cloud version of ERP systems (Figure 2), with usage options including hosted, manage - 48.3%, or SAAS - 51.7% [14]. PCG has identified the reasons why companies do not always choose a cloud solution. The largest part of respondents (40.91%) has insufficient information about the operating conditions of the system in the cloud; mistrust of information protection is observed in 27.27%.
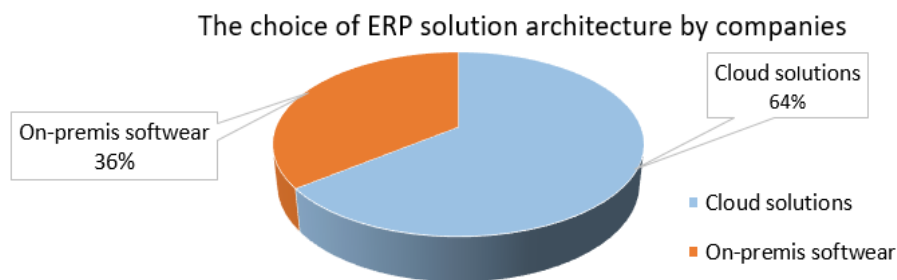

Figure 2. Distribution of companies' choices between cloud services and local system placement in the world [14]

To choose the optimal solution for their needs, companies should familiarize themselves with the offers and conduct an audit of their business processes and needs while weighing the risks and benefits. In 2022, less than half of organizations used a phased approach, while more than half used either an all-at-once approach or a hybrid approach. ERP Microsoft Dynamics 365, SAP S/4HANA, and Oracle are the most commonly used ERP systems among the 32 considered systems by PCG.

3. COMMUNITY'S INFORMATION PROCESSES STUDY DURING THE FORMATION OF A DIGITAL SPACE ON THE ERP PLATFORM: CASE OF UKRAINE

In 2023, there are 1,439 territorial communities functioning as administrative centers in 24 regions of Ukraine, except for temporarily occupied territories [15]. This study employs data gathered during advisory consultations provided by the Department of Information Systems and Technologies at Poltava State Agrarian University (PSAU) in the Poltava region. These consultations were conducted in 18 different communities, and four pilot projects were discussed to establish a unified digital information space through modern ERP systems. The aim was to improve the efficiency of management of all processes and resources and to further implement 4.0 technologies. The selected communities had a population of 24,000 and were managed by the executive committee of the city council. Figure 3 illustrates the general structure of these communities.

The executive committee of the city council manages several departments, some of which are similar to enterprises (such as accounting, finance, land, legal, and communal management). They also have collaboration and contacts with external organizations. The objective of this study is to combine the activities of all structural units of the executive committee of the city council and other organizations and enterprises in a single information space.

There are several unique aspects to this task:
1) The city council consists of separate departments that do not engage in production but have a staff, an accounting department, deal with budgeting, conduct analytics, manage budget expenditures, cooperate with budget-forming organizations, and keep records of communal property.
2) Budget-forming enterprises have separate accounts, conduct accounting and management operations, and submit accounting and financial reporting to relevant organizations, including the city council.
3) Communal enterprises of the city council perform joint tasks of providing services to citizens of the community and keep financial records of resources and operations, partially financed from the budget of the city council.
4) The city council supports several secondary educational, cultural, social, and medical institutions. Budgetary funds are distributed to them, and reporting, accounting of fixed assets, and other types of provisions are conducted.
5) Document circulation is conducted between all constituents and external counterparties, state authorities, and various meetings, planning, and discussions of strategies take place.

Results of the analysis of information activities and software of enterprises of the territorial community
Thus, the executive committee of the city council's activity involves a set of information flows classified as business processes, budget activity and analytics, legal activity, land accounting, etc.
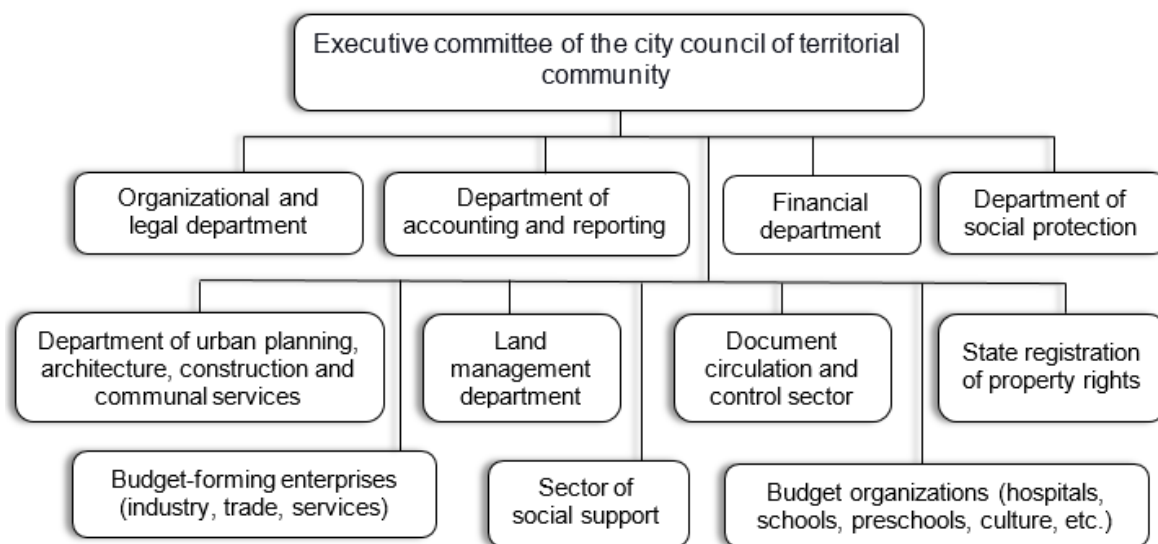

Figure 3 – Diagram of the organizational structure of the Executive committee of the city council

The management of information and business processes in the organization is approaching a crisis state. The city council leadership has initiated the transition from old management methods and software products, aiming to automate all information and management processes on a single platform of the ERP system.

The top-down initiative in this situation is positive, as it reduces the period and complexity of staff adaptation to new conditions, and the decision-making center for the project coincides with the proposals of project stakeholders.

One of the first questions that arise is which processes (accounting, management, financial) should be automated first. What approach to automation should be chosen for such an organizational structure? Ultimately, which of the known ERP systems will be the most effective for implementation in the organization?

University scientists, in collaboration with city council specialists, analyzed the functionality of the most popular international and domestic ERP systems in Ukraine [16-19], as well as the conditions of implementation projects, deployment, cost, and availability of post-project technical support. The results are presented in Table 1.

A thorough analysis of ERP systems based on various sources [16-19] has revealed that these systems share a common set of functions, which automate the management of production, procurement, finance, personnel, costs, sales, budgeting, analysis of indicators, accounting according to legislation, payroll, GPS monitoring of transport management, and electronic document management. Additionally, the systems offer Customer Relationship Management (CRM) modules and cloud solutions of the Software-as-a-Service (SAAS) model. Domestic systems have an edge in reporting documentation and integration with other systems of domestic production, such as electronic document management.

Table 1. Main advantages of choosing and using well-known ERP systems

The name of the ERP system	Summary of the main advantages and characteristics of each system
Dynamics 365 (Microsoft)	Typically serves small to mid-sized organizations with $250 million to $750 million in annual revenue. An open system: the development and expansion of functionality are handled by the Microsoft company (one of 72 solutions of the Microsoft ecosystem), and partners from all over the world adapt to the laws of countries. There is localization for 90 countries (as of June 2022); teach users how to use the system and customize Business Central if the customer wants to cover individual non-standard business processes. It is possible to collect consolidated reporting in a single system from at least a dozen countries where companies have branches, to centrally make changes to processes without additional settings for each company, the usual Microsoft interface.
SAP ERP	Full automation of many work processes in large enterprises with a large number of workplaces, a complex production process. Adapted to Ukraine, it has all possible tools for controlling finances, accounting, and expenses. Automated with a separate CRM module or others
IT-Enterprise ERP (IT Enterprise, Ukraine)	It has an open platform, several industry solutions that can work both in the cloud and the installed version, are suitable for both service and production business processes, configured to manage large enterprises. High level of technology and automation in the market.
Universal 9 ERP (SoftPro, Ukraine)	A multi-level complex solution for the formation of a single information space of any enterprise or organization. Has a set of contours that the client chooses as needed; flexible configuration, and integration with other systems: CRM or separate electronic document flow. They have a line of solutions for small and medium enterprises to large enterprises and corporations.

Based on this analysis, the "Universal 9" ERP system of the SoftPro company, which has a successful track record of over 30 years in implementing ERP systems in major industrial enterprises in Ukraine and other organizations, was selected for pilot projects.

The analysis of the organization's activities in collaboration with key specialists helped to identify problems that require precise solutions due to the introduction of a single ERP management system. Our survey of leading specialists from various organizations and enterprises operating as part of the territorial community and with various sources of funding has revealed the presence of different accounting departments, including accounting, contract accounting, cash accounting, salary and personnel, accounting of tangible and intangible assets, accounting of goods and material values, accounting of transport, and production accounting. These departments use different information systems, which can be grouped into accounting and tax reporting systems, accounting systems, specialized IT related to the specifics of the organization, and general-purpose software such as MS Word and MS Excel. Unfortunately, the accounting software is incompatible with the outdated personnel management system and attempts to integrate them have been unsuccessful.

Basic software complexes are hindering development. Until recently, individual departments and enterprises operating as part of the city council had sufficient basic tools. However, due to the implementation of local self-government reforms, tax changes, requirements for electronic document flow, land reform, and other factors, the current program is insufficient and inhibits market

advancement. As a result, opportunities for global growth are limited, and losses of budget revenues are being observed. It is, therefore, necessary to form a single software ecosystem on an ERP platform that is more flexible to support growth.

To implement a new ERP system, we can use project or standard technology. Our organization's management is considering the option of project implementation, which involves a pre-project study of the state of information processes management, existing databases, available technical support, and development of a technical task compatible with the executor, thereby reducing the risks of implementation and obtaining the predicted and intended result.

Details of the preparation of the ERP system implementation project

For the successful realization of the IS implementation project in the organization, we have prepared its description, indicating the goals (SMART rule), tasks, expected results, necessary resources, and financial support. The project's description is the result of joint work by a group consisting of leading specialists of the organization, representatives of Infosvit IT Service LLC, and scientists of PSAU.

The selection of a project solution was determined by several peculiarities of the organization, which make it necessary to create a special project. These peculiarities include:

1) The complexity and scope of activities and tasks of automation cover a significant number of management and accounting contours, such as production, trade, warehouse, procurement, budgeting, personnel, and more.
2) The need to control the timing of implementation and the size of the allocated budget.
3) The automation of a complete set of business processes within the organization is envisaged.
4) At the beginning of the project, there is a vision of how the information system should work, but there are no clear requirements for the elements of the system.
5) There is no relevant industry solution at the time of implementation.
6) During the implementation of the project, it is necessary to monitor the progress of tasks.
7) It is necessary to monitor the budget development at the various stages of the project.
8) There is a need for resource planning, such as specialists, time, material support, and communications.
9) The need to minimize losses when switching to a new system.
10) The automation objects are geographically dispersed.
11) There are several legal entities with different account types that require automation.
12) Integration with other systems is planned in the future, such as electronic document flow for local self-government and GIS-system Kadastr.UA.

The project solution also takes into account the need for monitoring and control of progress, budget development, resource planning, and integration with other systems. By addressing these challenges, the project solution minimizes losses and ensures a smooth transition to the new system.

To implement the ERP system effectively, a four-phase model of the project life cycle has been chosen. The model includes the following phases:

1) Analysis of business processes: The IT company, in collaboration with the customer's representatives, analyzes the efficiency of the business processes. If required, they reorganize the processes, build an information model of the system based on the principle of "how it should be," and formalize it into a technical task.
2) Adaptation of the system and trial operation: This phase is divided into several stages, each corresponding to a logical business process. At this stage, it is crucial to model the system's performance in various critical situations to minimize risks before it is put into industrial operation.
3) System launch: In this phase, a large volume of existing information that cannot be lost is transferred to the system environment. Key indicators obtained from predecessor systems are also checked. Before starting the system, a "clean" data import is performed.
4) Service, support, and development: The supplier company provides technical support to the customer's specialists as part of the implementation contract.

During stages 3 and 4 of the project, personnel must undergo initial training to learn the new system. The IT company employees, along with Poltava State Agrarian University teachers, plan the training. The experience of the university's cooperation with IT companies has been used for more than 5 years [20]. Senior students are involved in the processing and transferring of previous data to ease their adaptation to the conditions of professional activity. The Employers' Requirements-Oriented Study is described in detail in works [9, 10].

To customize the ERP system modules for specific organizations, the IT company creates the company's database model based on Oracle technologies. They also significantly refine program codes at the level of the system's programming. The "Universal" core is created using programming languages such as Alaska Xbase++, SQL/SQL scripts, Delphi, MS VBA, and popular web technologies like HTML 5&CSS3, PHP, JavaScript, Java, and others.

Before selecting and implementing a specific version of the "Universal" system, a comparison of the automation needs and the chosen solution's capabilities is necessary to avoid redundancy and unnecessary costs.

Most of the structural elements of the Executive committee of the city council are budget organizations with the same accounting methods, while individual enterprises and the

territorial community council itself are not prepared to invest a significant amount from the budget for technical re-equipment. Hence, the latest version of the cloud-based "Universal 9" ERP system has been implemented, which incorporates all modern technologies for processing large volumes of data, user interface, and architectural solutions, and has all the advantages of cloud solutions. The structure of the "Universal 9" architecture is schematically presented in Figure 4.
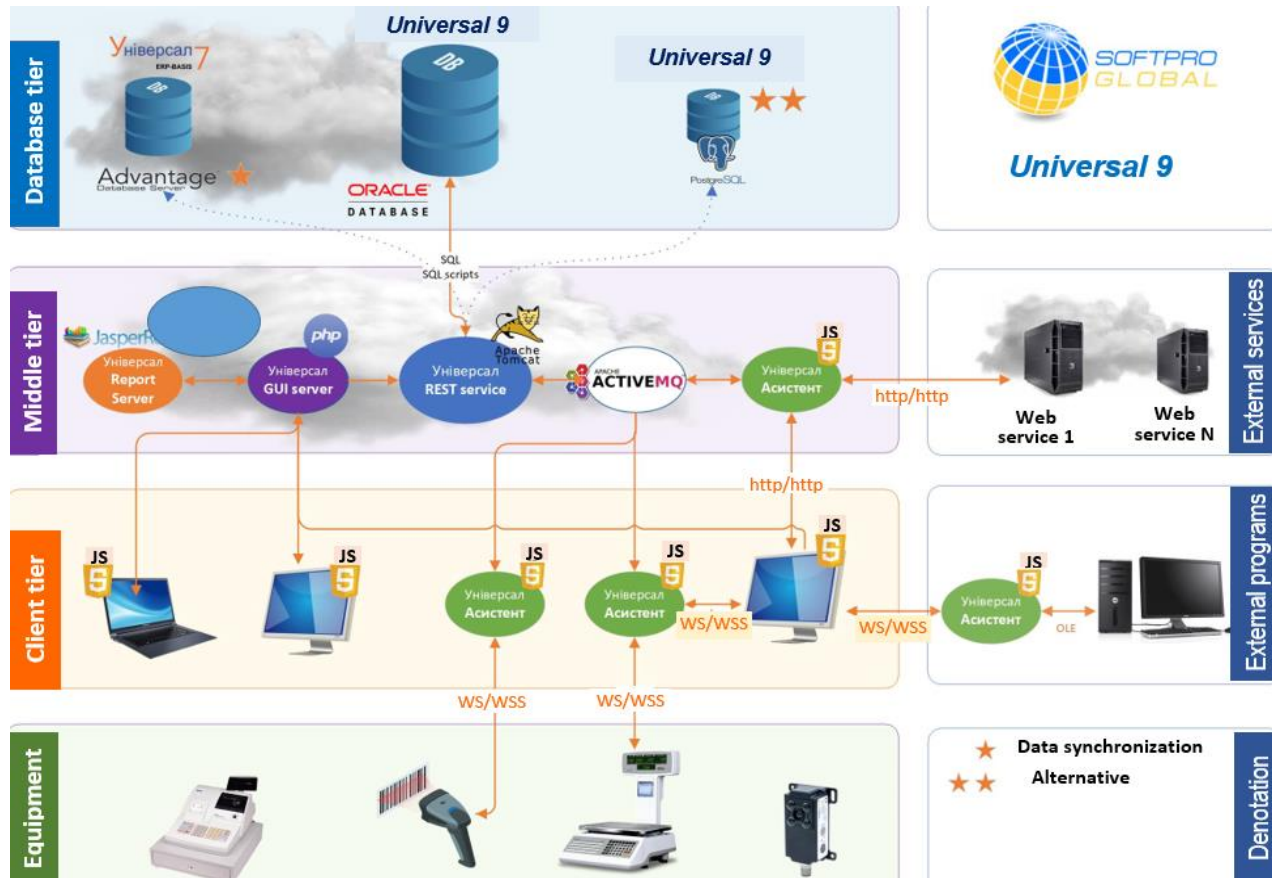

Figure 4. Multi-layered client-server architecture implemented in the "Universal 9" cloud (based on [19])

This architecture built according to the principle of a multi-tier system that contains and processes huge amounts of data that come from both users and various equipment.

The advanced architecture of ERP "Universal 9" makes it possible to scale the system to most enterprises in the future, including those that plan to use special sensors to collect operational data from hundreds of meters using a combination of artificial intelligence and Internet of Things (AI + IoT) technologies based on algorithms described in [21-22]. System developers abandoned Windows client applications in favor of Web-oriented thin clients, for which one of several popular web browsers is sufficient. This approach significantly reduces the costs of deploying and maintaining client applications of the system. The transition to utilizing a selected ERP system in a workplace environment commenced with the implementation of the accounting circuit. One of the primary tasks for launching the system in the organization was the creation of a new database model and transferring data from existing accounting systems to the new platform.

For organizations with complex structures (as illustrated in Fig. 3), "Universal 9" offers the key advantage of being able to manage several enterprises with different accounting schemes in one database, encompassing both accounting and operational accounting.

Each enterprise and accounting type within each structural unit is represented as a single linear list of charts of accounts. The same operation can be displayed according to specific rules in one or both charts of accounts. The core system enables accounts to be presented in different currencies and according to different customized standards. This architecture allows for several "spaces" to be located in one database, each of which stores a list of "its" enterprises. In turn, each enterprise has two levels of accounting: accounting and operational accounting. The developers themselves present such an accounting architecture using the example scheme shown in Figure 5. This approach facilitates making unified centralized settings and administration rules for several organizations (enterprises) with subsequent data exchange between them.
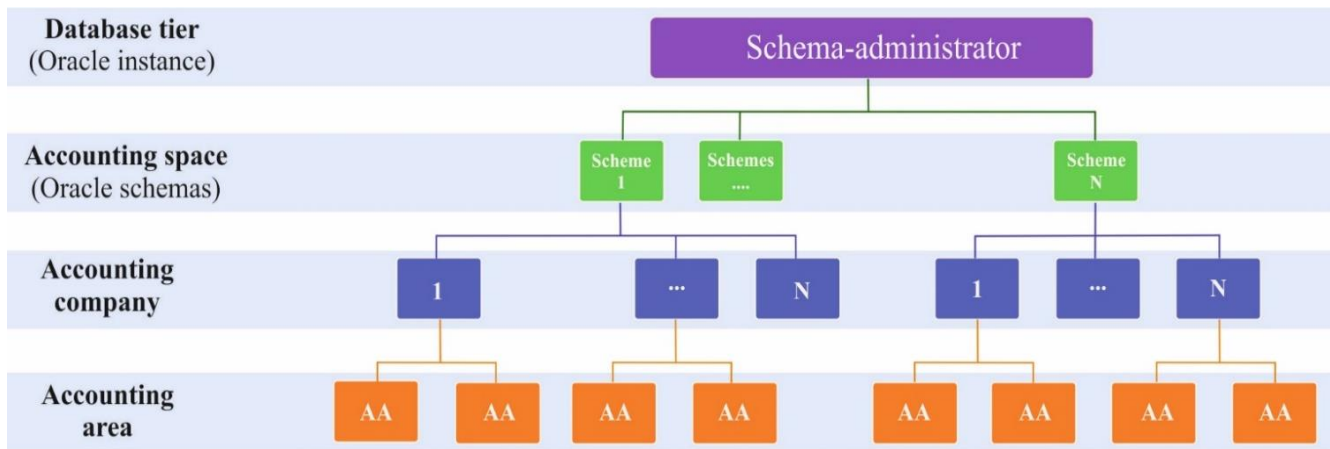
Figure 5. Schematic representation of corporate accounting architecture in "Universal 9" ERP for Community

Technically, this approach allows for creating a test enterprise, carrying out settings on it, transferring the settings to the main (dispatch) scheme, and then applying them as needed for existing enterprises.

4. CONCLUSIONS

As many enterprises and organizations move towards implementing Industry 4.0 technologies (Economy 4.0, etc.), they must first reform their automation of production and management processes at the 3.0 level. In many cases, this is accomplished on the platforms of modern ERP systems. The type of organization considered in this work, such as the executive committee of the city council of the territorial community, is not a typical representative of business or industrial enterprises but rather has a complex organizational structure comprising various divisions or individual enterprises.

They have their codes in the registers of enterprises and organizations, and charts of accounts, and some of them are taxpayers and budgetary organizations of the territorial community. The presence of various types of software, applied IS, the loss of effectiveness in solving common tasks, and the need for complex analytics and control prompt managers to modernize the management and accounting system by creating a single information space on the platform of a modern ERP system.

Upon completing the formation of a single information space for managing the operational and prospective activities of local self-government bodies, it is worth emphasizing the benefits that most enterprises and departments will receive after transitioning to the ERP platform:

1) A common database that centralizes information from many departments and provides a consistent cross-functional view of the company.

2) A consistent user interface (UI) and user interaction (UX) across departments and roles. The ERP's Inventory, HR, and Finance modules share the same look and functionality, provided they are sourced from the same vendor. A consistent UX and UI also drive efficiency, as users can quickly find and understand information from all corners of the business.

3) Integration of business processes. ERP is capable of supporting and integrating a diverse set of processes that make all kinds of business and other activities successful. This increases productivity and visibility and therefore lowers costs.

4) Automation of repetitive tasks, reducing manual data entry and sometimes duplication, saving time, and minimizing errors.

5) Data analysis is one of the most valuable aspects of ERP that breaks down information silos. The ability to mix and match data from almost any part of a large enterprise organization into in-depth reports reveals areas that are performing exceptionally well and those that are not meeting expectations. Leaders can analyze problems and start solving them immediately.

Further research should focus on developing a stack of technologies that can integrate with the cloud ERP system, leading to the creation of a modern software landscape that aligns with the Industry 4.0 framework.

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