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SAP UCC

SAP University Alliances

Proceedings of the

1st SAP UA Community Conference

Central and Eastern Europe

28-29 Oct. 2024, Budapest, Hungary

Message from the General Chair

The recent SAP University Alliances Community Conference Central and Eastern Europe 2024 Budapest brought together academic and industry leaders to discuss the latest advancements in SAP education, technology integration, and AI-driven automation. This October 2024 conference provided an exceptional platform for sharing teaching innovations and exploring the transformative potential of SAP solutions across Central and Eastern Europe. Highlights included in-depth sessions on SAP Education and Analytics; Technological Developments and Integrations; and Artificial Intelligence and Automation. These sessions addressed the complexities of SAP in academic settings, real-time business process optimization, and the implications of AI for the intelligent enterprise. In addition to promoting knowledge exchange, the conference aimed to strengthen collaboration within the SAP University Alliances community, further enhancing the educational foundation for future SAP professionals across the region. This inaugural event marks the beginning of a new tradition in the SAP academic and professional landscape.

Udo Bub

Professor and Institute Director at Eötvös Loránd University (ELTE), Faculty of Informatics, Budapest

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Content

Modeling the business ecosystem context for SAP products in education

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***Abstract*— In the last decades, SAP has provided a large variety of software products which construct a huge family. However, since SAP products are to be recognized and learnt, there is an issue of how to teach this software to ensure its real usage. Although SAP software developers and engineers provide very intuitive products, the learners still question the necessity of using particular pieces of software. This paper presents an enterprise architecture model based on two leading modeling techniques, i.e., Archimate modeling language and the BPMN notation, to emphasize fundamental concepts in a business ecosystem. The study highlights the necessity to learn the SAP S/4 HANA system in a certain business context, to better explain the software functionalities and provided values as well as to justify investments in the SAP product. Secondly, this study reveals that SAP S/4 HANA education process should support the development of specific competencies of end users, which are are required by today's market.**

Keywords*— *SAP S/4 HANA, business ecosystem, Enterprise Architecture, competence, business process

I. Introduction

Although the SAP products are recognizable and acceptable by companies integrated in value chains, there is still an open question how to persuade others about the SAP software values and how to teach the SAP integrated system to ensure its wide application. The SAP integrated systems have been successfully implemented for years and the business process reengineering was the fundamental necessary condition of their successful implementations. Nowadays, enterprises are increasingly interconnected in various collaborative networks. Hence, they constitute business ecosystems, in which firms cooperate with their customers, suppliers, competitors, and other business partners, e.g., governmental agencies [1].

The general purpose of this study is to outline the Enterprise Architecture (EA) context for the SAP S/4 HANA Global Bike fictitious company, which is considered as a certain business ecosystem developed by SAP for educational purposes [2]. In this study, authors highlight that the process approach and capabilities development are fundamental for the integrated system usage. Authors argue that the integrated system learning course should include the business ecosystem context considerations, hence they propose to define that context in the EA modeling languages, i.e., ArchiMate and Business Process Model and Notation (BPMN). The rest of the paper includes the following. The second section is on the business ecosystem context defining and EA modeling. In this section, authors focus on process and capabilities modeling. The third section covers a case study on SAP S/4 HANA Global Bike usage for educational purposes. In this section, authors have identified SAP S/4 HANA capabilities. The fourth section covers a contradiction of competences developed in SAP S/4 HANA learning process created and competencies required by markets. Such comparison permits revealing gaps in the learning process. At the end of the paper, authors provide conclusions and recommendations for educators of SAP S/4 HANA.

II. Business Ecosystem Context

In this study, authors propose to focus on an ecosystem context identification and description. The information system context may be identified with the location, time, the state of people, and computational and physical objects [3]. Seffah and Javahery [4] argue that context is „any information that can be used to characterize the situation of entities that are considered relevant to the interaction between a user and an application, including the user and the application themselves". Considering the context for information systems or software learning seems to be necessary, because the goal of context acquisition is to determine what a user is trying to achieve. However, because sometimes the user's objective is difficult to define directly, the context usage may be helpful to recognize what software application and how to best support the user [3]. A context is not simply the state of a predefined environment, but it is a part of a process of interacting with a changing environment consisting of various, reconfigurable resources [5]. Alshaikh and Boughton [6] have said that the term context in software engineering has been typically associated with the act of setting system boundaries or scope. As context is recognized as boundaries, the context is identified in the form of interfaces between internal and external entities, thus context plays a role in defining functional and non-functional requirements for all architecture interfaces. In the learning process, the context of the learner consists of earlier acquired knowledge and skills, recognized conceptual models, cognitive capability, motivation, location, and spatial and social environment [7].

In this study, authors formulate a thesis that the ecosystem context, as well as the internal processes in an enterprise can be successfully supported by the EA management approaches. According to Chalmers Musukutwa [8], the EA is a process, by which a business organization standardizes and organizes its Information Communication Technology (ICT) infrastructure to align with its business vision and strategic goals. The EA provides a holistic approach to analysis of all ICT and business issues [9]. Business organizations develop and apply the EA frameworks to describe their enterprise architectures in a unified, understandable, and compatible way. The EA frameworks usually include various viewpoints and models, which are expected to support the architects in abstracting the details of the design tasks and produce models coherent with the architectural descriptions. The enterprise architecture presentation requires description of principles, methods, models, modeling languages that are used in the EA designing and next identification of enterprise organizational structure, business processes, information systems, and IT infrastructure. Chalmers Musukutwa [8] argues that the SAP Enterprise Architecture Framework (SAP EAF) is based on the TOGAF [10] framework and enables creation of the

following artifacts: requirement list, business architecture, data models, data flow diagrams, and other components of enterprise architecture, i.e., organizational structure schema, business capabilities, Information Technology (IT) capabilities, and IT infrastructure description. The IT capabilities enable a firm to acquire, deploy, and reconfigure IT resources to support and enhance business strategies and processes [11]. Simultaneously, the information management capability is understood as an ability to provide information to users with the appropriate levels of accuracy, reliability, security, and confidentiality.

A. Business Process Modeling

Business process modeling and management include describing how business activities interact and relate with each other, and how they are connected with other business elements, i.e., goals, resources, decision points, events, rules, and actors. Quite many languages for BP modeling are available today. They are generally divided into four major categories: traditional process modeling languages, object-oriented languages, process integration languages, and dynamic process modeling languages [12]. Business Process Model and Notation (BPMN) has recently become one of the most widely used languages for modeling BPs, and it was accepted as the ISO/IEC 19510 standard [13]. BPMN notation is defined by the Object Management Group (OMG), with the 2.0.2 version existing since 2014 [14]. BPMN was designed to be understood by business analysts, technical developers, business managers, and more [15].

B. Capabilities

According to Sinkovics et al. [16], capabilities are defined as the resources needed to produce and manage technical change, containing skills, knowledge and experience, and organizational structures and linkages. Capability is an individual or a firm's ability to deploy or synchronize different arrangements of resources through a firm's processes [17]. For example, there are planning capabilities, production management, sales and marketing capabilities.

III. Case Study on SAP S/4 HANA Global Bike EA

The integrated information systems have revolutionized business organizations thirty years ago, through reengineering their internal and interorganizational processes. The companies are strongly dependent on their suppliers, i.e., Small and Medium Enterprises (SMEs), as well as on customers and other institutions. Instead of competition among firms, nowadays, the supply chains compete one with another. Therefore, consideration of enterprise architecture can be replaced by modeling the ecosystem architecture. This case study was conducted in the setting of bicycles' manufacturers located in Germany and USA (Fig.1). Data were gathered through an analysis of the SAP S/4 HANA documentation for end-users. The company name is Global Bike and its ArchiMate language ecosystem architecture is included in Fig.1. Contextual factors affecting the SAP S/4 HANA exploitation are namely Global Bike business processes, i.e., Source to Pay, Hire to Retire, Design to Operate, Lead to Cash, Request to Service, and Record to Report. Those processes are originally provided by SAP as implementable in enterprises applying SAP software. Modeling the SAP integrated system context encourages the questions that form a starting point: what strategic goals will the integrated system help in achieving? Who are the stakeholders and how will they use the integrated system? What standard will be used for documenting the processes? What competencies are required to successfully use the software? Teaching SAP S/4 HANA for the Global Bike requires answers to those questions, because students request for justification why the SAP software is needed as well as an explanation of the context of that usage.

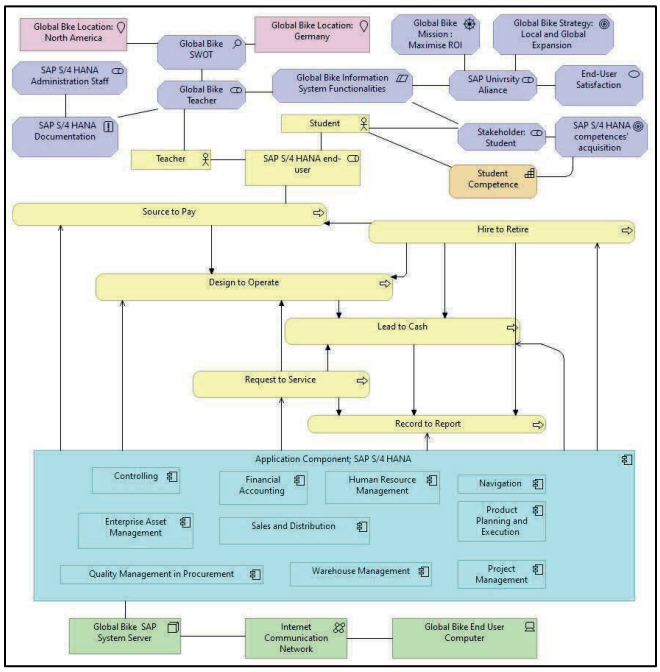

Fig. 1. Global Bike Enterprise Architecture model.

The Fig.1 includes the Global Bike EA stakeholders, i.e., SAP University Alliance, SAP S/4 HANA administrative staff, teacher, and student. For them, the SAP S/4 HANA documentation covers the principles determining the software usage. For this Global Bike company as for each other business unit, the authors define goals (e.g., local and global expansion) and mission, i.e., maximize ROI, and assess strengths, weaknesses, opportunities, and threats (SWOT). In the EA model, the Global Bike information system functionalities are constraints, because the SAP S/4 HANA is available in a limited educational version. Anyway, the authors assume that the SAP University Alliance is interested in creating value, i.e., end-user satisfaction, and the learners have a very pragmatic goal, i.e., competence acquisition. In this study, authors assume that students as well as a teacher play the role of the SAP S/4 HANA end users. Core capabilities are the business capabilities that generate the most value within the business. A role is a character assigned or a function performed by the end-user. The value proposition focuses on what a company offers to its customers or beneficiaries. In this case study, the SAP University Alliance is the company, which created the Global Bike and which has the most to offer its customers. Activities performed by end-users are included in business processes, hence the presentation of a network of processes seems to be necessary for learners.

As part of its training program [18], SAP offers the course "Integrated Business Processes in SAP S/4HANA"[19]. This course provides the knowledge necessary to understand the work of the end-to-end business processes of a highly integrated SAP S4/HANA system; being valid both for SAP S4/HANA Cloud and on-premise. Among others, the course provides understanding of such processes as Financial

Accounting (FI), Human Capital Management, Warehouse Management, Asset Management, etc. Also, it focuses rather on the components of the processes than on the flow of these processes (i.e., the sequence of steps taken to achieve certain result)[19]. However, the course is not freely available to the learners and cannot be extensively used by educators in the academia, as part of their courses on SAP S4/HANA.

There are many materials provided by SAP for educators. However, due to the fact that the Global Bike company data and processes, provided by SAP for education, are very substantial and cover many modules in SAP S4/HANA, it would be reasonable to state that the sequence of processes and the ways they are connected together requires arranging. It would allow both the educator and their students to understand the levels of complexity of each process and sub-process taking place within the Global Bike structure, to define and understand possible bottlenecks and milestones in these processes. In this paper the authors suggest using BPMN to model Global Bike processes in SAP S4/HANA. As it was mentioned before, this notation is quite complex and that allows to use it for modeling some compound business processes. On the other hand, the elements in BPMN are rather intuitive, easily learned and understood. Based on the education materials available for the authors through SAP S4/HANA Fiori interface, the authors take an attempt of suggesting the models for a set of processes taking place in SAP S4/HANA Global Bike environment in the education process. The processes considered are: Materials Management, Project Management, Sales and Distribution, Warehouse Management, and Financial Accounting and Controlling. Fig. 2. presents the general view on the process flow, where all the included processes are presented as collapsed sub-processes (rounded rectangles with pluses). Between these sub-processes there are intermediate events (double-lined circles) used to indicate certain results obtained after a process is completed. These results allow the succeeding process to begin. For instance, after the Project Management process is completed, there are products manufactured and ready for potential sale – this is when the Sales and Distribution can be started. When payment for sales is received, there comes the turn of Financial Accounting and Controlling processes. Such intermediate events can be also considered as milestones of the whole process flow. The Warehouse Management is placed in parallel with the other three processes since warehouses are engaged in the processes of manufacturing, sales, and controlling. Moreover, the authors suggest that before proceeding with the Global Bike in the system, a user needs to get familiar with the SAP S4/HANA navigation – which is shown as the first task of the process in Fig.2. This combination of processes is an example of combination of processes, proposed by authors in this study. In a more complex and, perhaps, thorough approach towards SAP S4/HANA education with Global Bike data, the authors suggest performing two additional steps before actually building a model with BPMN. The first step is providing short descriptions to the processes to be modeled. That would be required, first of all, for the complex processes – which contain a few (or many) sub-processes inside. Providing brief explanations of the purpose of each sub-process might be useful for the education process. Yet, this step can be omitted if an educator provides students with other useful materials on the discussed processes. The second step, which the authors consider more valuable, is process identification. The purpose of this step is to take a very close and thorough look at each process and sub-process modeled. To reveal all the possible bottlenecks, define participants, understand connections with the other processes. The limits of a process should be set in the following steps [20]: (1) set the goal of the process; (2) define trigger and outcome events (start and end events in the model), as well as the first and the last steps of the process; (3) point out the process(es) that are preceding and subsequent to the selected one; (4) define resources and success factors; (5) reveal expectations of customers of the process – people directly engaged in the process; (6) expectations and requirements of suppliers of the process – those not directly engaged in the process (may be skipped due to the absence of suppliers for some processes). The stage of identification could be performed prior to modeling in BPMN, but also – after the models are built. In this case the identification would allow us to review the models and provide changes into them. If that is nor required, the questions about success factors and resources, suppliers and customers – will allow the students to think critically and to analyze the processes more deeply.

In the EA modeling, capability is associated with business concepts, e.g., goal, process, resource, actor. According to Alvarez [21] business capabilities are „hidden" in processes, information and data, technology, and people, e.g., internal and external stakeholders' knowledge, skills, experiences and social competences, organizational structure, or decision making frameworks. The Fig. 3 includes the authors' proposal of capabilities needed for SAP S/4HANA. The basic business capabilities result from the software system functional decompositions. The capabilities are expected by students to be acquired in the learning process. Usually, students have a prerequisite knowledge to be able to acquire new one, as well as they have the IT competences, and analytics skills as the necessary prerequisites to the further studying. Following the publications provided by Alvarez [21] and Hassan [22], authors proposed the SAP S/4 HANA capabilities identification (Fig. 3). Therefore, for example Human Capital Management requires management capabilities concerning employee identification, organizational structure design, employee profile management. Beyond that, Employee Analytics Management capability is needed. Analysis of the Fig 3 permits for inference that SAP S/4 HANA usage requires management capabilities, i.e., finance, logistics, quality management, product management, project management, and human capital management. Hence, the end users should have management, finance, controlling, logistics competences. Beyond that the analytics and IT competences are needed. However, other competences, e.g., marketing or system conversion, software customization with ABAP are not included in the SAP S/4 HANA learning process, and they would need a separate software and learning time.

IV. Development of Professional Competencies in SAP Education Driven by Today's Labor Market

The concept of „competencies" is interpreted in various disciplines, including management, psychology, and pedagogy, and depending on the context, it has different meanings. The word „competency" comes from the Latin „competentia" and means: adequacy, compliance, scope of authority, authorization [23]. The European Parliament (EP) recommends eight core competencies essential for functioning in a knowledge-based economy, which should be developed through lifelong learning [24]. The EP and EU Council Recommendation on core competencies served as a

determinant for the development of the Polish Qualifications Framework (PQF) by experts. PQF is a reference system for qualifications awarded in Poland. There are 8 levels in the PQF. Each of them is described by means of the general characteristics of the scope and complexity of knowledge, skills and social competence required from persons with a given level of qualifications. In the PQF, the typical characteristics of qualifications given in general, vocational and higher education are taken into account [25]. In the higher education system, qualifications are described in the form of learning outcomes for each subject in terms of knowledge, skills, and social competencies. Therefore, the term „competencies" also refers to the dispositions that a person achieves throughout their life through learning. They indicate the level of proficiency that conditions effective action in a given field [26].

To diagnose the demand for employee competencies in SAP S/4 HANA software on the Polish job market, a study was conducted. It covered job postings published in July 2024 on the following portals: indeed.com, infoPraca.pl, LinkedIn, nofluffjobs.com, oferty.praca.gov.pl, rocketjobs.pl, and theprotocol.it, which included the key phrase "SAP S/4 HANA". Access to 250 job postings was obtained (Table I). A detailed analysis was conducted on job postings available on the portal indeed.com [27]. During the study, a distinction was observed between the sought-after competencies related to SAP S/4 HANA software, categorized into technical and end-user (functional) competencies, assessed in terms of knowledge and skills, as well as social competencies

TABLE I. NUMBER OF JOB OFFERS WITH THE KEY PHRASE "SAP S/4 HANA"

Name of portal	Number of offers
indeed.com	75
infoPraca.pl	43
LinkedIn	92
nofluffjobs.com	7
oferty.praca.gov.pl	1
rocketjobs.pl	5
theprotocol.it	27

The analysis classified 28 job postings as requiring technical competencies and 47 as requiring end-user competencies. Based on this, a list of the most desired competencies in today's job market was created.

A. Technical competencies include:

- Proficient knowledge in HANA, UI5, FIORI and SQL.
- Experience in implementing, migrating, and optimizing SAP systems, especially transitioning from earlier versions of SAP ERP to SAP S/4 HANA.
- Designing robust and scalable IT architectures that align with business goals, with deep knowledge in integration, preferably SAP Cloud Platform, and SAP product and architecture knowledge.
- Experience in SAP Analytics Cloud.
- Proficiency in configuring and customizing SAP Quality Management (QM) solutions to integrate with other SAP modules (e.g., Finance (FI), Controlling (CO), Sales and Distribution (SD), Material Management (MM), Production Planning (PP) and external systems, ensuring smooth data flow and process alignment.
- Basic to strong ABAP know-how with proficiency in reading and understanding ABAP code.
- Defining Process Integration (PI) or ABAP interface programs with third-party entities (e.g., invoicing, EDI), including simple debugging, Business Application Programming Interface (BAPI), Business add-ins (BADI) and user queries.
- Knowledge and experience with key integration points with other SAP modules such as Ariba, MDG, and FI.
- Test automation expertise.
- Advanced experience in integration with Warehouse Management System (WMS).
- Management and resolution of WM issues, along with effective communication during the roll-out process.
- Ensuring compliance, security, and efficiency within the SAP S/4HANA access control framework covering various aspects of access management from advising and approving access requests to collaborating with stakeholders to optimize access roles.

B. End user competencies include:

- Good understanding of industry and IT trends as well as business processes in the following areas: Manufacturing, Procure-to-Pay (P2P), Supply Chain and Logistics, QM using inspection plans/inspection lots, WM including eWM and Classification/Batch Management.
- Familiarity with the functions and capabilities of SAP S/4HANA in the following modules: FI, CO, SD, MM, PP, QM, Plant Maintenance (PM), Project System (PS), Human Resources (HCM/HR), Supply Chain Management (SCM), Advanced Planning and Optimization (APO) and providing functional support for these modules.
- Understanding of cross module dependencies (PP/PI, QM, FI/CO, MM, WM, SD) and MM, QM, PP master data.
- Deep understanding of financial processes such as accounting, asset management, financial consolidation, and financial reporting.
- Experience in the SAP FI module on S/4 HANA including general ledger accounting, accounts receivable, accounts payable, asset accounting, bank accounting, embedded analytics, reporting.
- experience in planning, coordinating, and driving large financial transformation projects,
- Experience in the SAP CO module on S/4 HANA including Overhead Cost Controlling, Product Cost Controlling, Profitability Analysis, Profit Centre/Segment Reporting, Material Ledger, Profit Center Accounting, Embedded Analytics, Project Systems/Enterprise Portfolio and Project Management (EPPM).
- Knowledgeable about SAP CO integration with other areas, including but not limited to SD, Supply Chain and Manufacturing.

- Operational data management of purchasing relevant information such as SAP contracts and price lists; creation and update of supplier master data; creation and maintenance of central training materials for the procurement process.
- Providing services and capabilities necessary to oversee and perform all conceptual and analysis activities in the Procurement area.
- In-depth understanding and hands-on experience with SAP MM and SRM (Supplier Relationship Management) modules on S/4 HANA, including configuration, customization, and integration.
- Ability to develop detailed plans, timelines and goals for Product Lifecycle Management (PLM) projects.
- Responsible for creating Bills of Materials (BOMs) and Master Recipe (MR), as well as implementing changes in the system for the non-Master Data Governance (MDG) part. This includes creating new material codes in the SAP S/4 HANA system for BOM and MR for finished goods; agreeing upon and confirming usage standards and recipes, making changes to BOMs and recipes according to current business needs, and implementing annual Annual Operating Plan (AOP) changes.
- Implementation of new customers based on a decentralized SAP WM system integrated with the S/4 HANA system.
- Perfectly familiar with Record to Report (R2R) processes.
- Functional consultant focused on Tax Area.
- Strong understanding of the P2P business process.
- Configure SAP QM modules to meet specific business needs, including quality planning, quality inspection, and quality control processes.
- Working as functional consultant SAP Deposit Management (DM) / SAP Banking Platform (BP) with a comprehensive module that enables banks to manage various financial instruments, such as fixed deposits and savings accounts.

C. *Social competencies include:*

- Past experiences with Agile Methods/Kanban.
- Experience in working in agile, virtual and cross-functional teams.
- Ability to act as liaison between the business and technical worlds.
- Supporting the collection and analysis of requirements from business departments and providing advice on functional, methodological and process-oriented solutions.
- Excellent communication and presentation skills, with the ability to design and deliver high-impact presentations.
- Quick understanding and the ability to provide and receive constructive feedback.
- Strong analytical and conceptual strengths.
- Result-oriented team player with strong analytical thinking and the ability to prioritize and organize work effectively.
- Ability to work autonomously with a high level of proactivity.
- Ability to manage conflict situations.
- Excelent command of English and German languages (written and verbal).
- Willingness to travel.

V. CONCLUSIONS

The rapid pace of change and the emergence of new technologies create the need for continuous verification of professional competencies and ongoing education within one's profession. The integration of knowledge and skills from various fields increases the ability to perform work in different positions, secure and maintain employment. The opening of labor markets, along with the rise in competition and mobility, means that more and more people are working outside their home countries. The scope of many companies' operations has become international. In this situation, the importance of cooperation and competition grows, while at the same time, there is a need for standardization, the ability to compare employees' competencies, and quick adaptation to new requirements. Therefore it is important to teach students that each company has its own ecosystem, that integrated information systems are based on the process management approach. Academicians argue that the EA modeling increases the system implementation effectiveness and supports an understanding of the whole enterprise [28]. Applying BPMN in combination with the process identification and delimitation procedure the educators can perform a detailed analysis of the processes of Global Bike GmbH taking place in SAP S4/HANA, providing their students with deep understanding of the whole operation – from purchasing materials through manufacturing bikes to selling the ready goods. Teaching integrated systems, i.e., SAP S4/HANA, preceded by an explanation of the essence of process modeling using Archimate, BPMN notation, or Signavio software significantly increases the effectiveness of teaching, i.e., brings higher grades due to greater interest and understanding of the enterprise's business architecture. The students not only learn to perform tasks in the integrated system but also realize the purpose of every task and the effects they have on further steps of the company operation. Over time, there is increasing awareness of competency potential, both among those already employed and those who will soon enter the job market. It is important to note that changes in the economic market and EU policies are leading to a redefinition of employers' requirements. This creates a need for continuous enhancement and adaptation of competencies.The considerations presented in this article can be used to improve the education process to better meet the demands of the modern job market.

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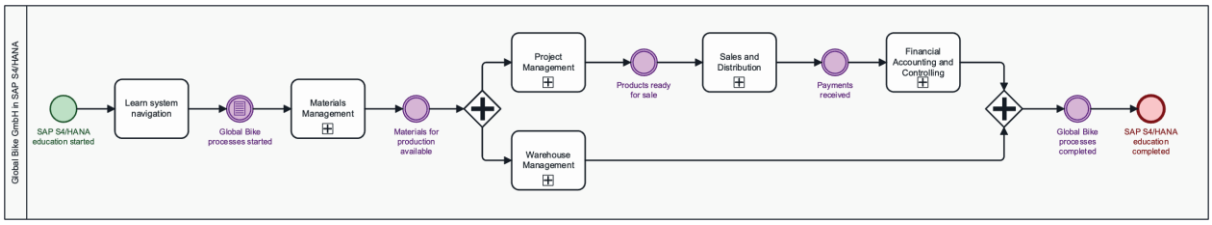

Fig.2. SAP S4/HANA Global Bike process flow: general view

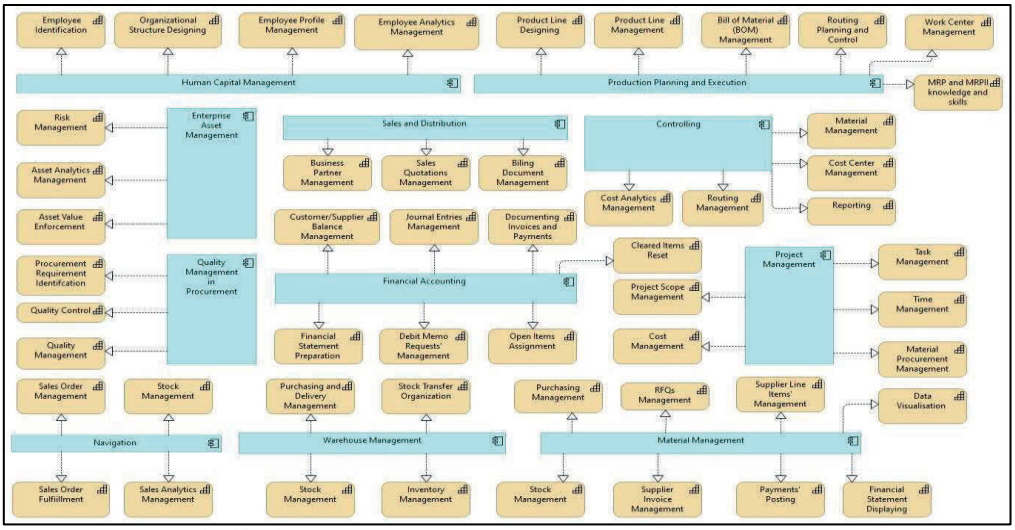

Fig. 4. SAP S/4 HANA Competence Identification

Proprietary vs. Open-Source ERP: The Case of SAP and Odoo

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***Abstract*—Getting Enterprise Resource Planning (ERP) systems into place is one of the key components that businesses need to drive operations, transactions, reporting, and process automation. While open-source solutions have achieved remarkable progress in nearly every software product category for businesses, ERP has remained mostly proprietary in real installations, and open-source ERP systems account for a relatively small percentage of the ERP market overall. This study compares many aspects of the industry leaders in proprietary ERP (SAP) with open-source ERP (Odoo) to examine the reasons for the dominance of proprietary ERP.**

Keywords— ERP, open-source, SAP, Odoo

I. Introduction

Any business or organization may succeed with the help of information technology. Putting Enterprise Resource Planning (ERP) systems into place is one of the key components that businesses need to drive operations, transactions, reporting, and process automation. Businesses often produce more at the lowest feasible cost and respond quickly to the constantly shifting needs and demands of both internal and external consumers.

An open-source is a software where the source code is available for other developers to use, modify and give enhancements. The product-associated revenue streams are shifted toward auxiliary products such as support, training, documentation, and others [16]. Unlike proprietary software, open-source software is available for use freely and modified under terms defined by the software license [17].

Open-source solutions have made significant progress across various software sectors within enterprises, but the implementation of ERP systems has remained largely proprietary, with open-source ERP solutions occupying only a small portion of the overall ERP market [8]. This article explores the factors contributing to the dominance of proprietary ERP systems and compares the characteristics of market leaders in proprietary ERP (SAP) and open-source ERP (Odoo).

II. Definition of ERP

From a process perspective, an ERP system is a comprehensive suite of IT applications that facilitates and supports enterprise operations [1]. ERP systems are software platforms that span the entire enterprise, utilizing an integrated database [2]. The support provided can encompass functions or processes. ERP software streamlines operations, data, and information flow throughout a company by combining essential business activities into a single system. [7]. This is critical for efficient resource management, improved productivity, and well-informed decision-making [7]. An ERP serves as a single source of truth, such as SAP S/4HANA's HANA database, for all enterprise operations [1]. Users of an ERP within an enterprise are diverse, including end users, auditors, consultants, employees, and developers. ERPs have evolved over the years in response to the evolving business and market dynamics in their implementation [2]. ERPs should be installed within a technical environment that supports and aligns with overall corporate operations and strategy in order to guarantee that they function as viable platforms for integration and value generation [2]. Enterprises are faced with the decision of choosing between proprietary and open-source ERP systems. However, deciding between open-source and proprietary options is not straightforward [3].

III. Research Objectives

There is a definite need to compare Odoo and SAP as they are two well-known ERP solutions on the market, each with unique features and capabilities catered to various company needs. SAP is proprietary and Odoo is open-source. A comparison of the two leaders on either model is a clear representation of the two different ERP software models. Khiller argues that open source has many developers and programmers who are least bothered by the idea of proprietary software, but on the other hand, the open-source poses a threat to the proprietary ERP industry [3]. This paper thus explores a comparative analysis of the proprietary and open-source software taking the case of SAP and Odoo to give some insight and guide to enterprises in their ERP implementations.

The research focused on the following objectives:

- To establish a comparative analysis of the proprietary and open-source ERP systems based on two market leaders.
- To gain insight into the implementation of proprietary and open-source ERP
- To examine the comparative implementation of SAP and Odoo
- To generate recommendations for better implementation of ERP in different environments as value addition.

IV. Proprietary vs. Open-source

An ERP system is considered proprietary when its internal code is not openly accessible to users and restrictions are enforced through the End User License Agreement (EULA). The EULA legally binds users to the terms and conditions governing the implementation of the ERP system [3]. Only the individual or organization who created the ERP software can make modifications to the source code [3]. The source code of the software is exclusive since its intellectual property rights are held only by the publisher or owner of the program. SAP is a prime example of a proprietary ERP system.

Open-source ERP systems are developed and tested through collaborative efforts, allowing anyone with the necessary expertise to access, modify, and distribute the source code [3]. The concept of open-source software originated from the GNU project in 1983 [3]. This collaborative approach aims to create software for all, enabling the sharing and editing of the source code with no restrictions for any purpose. This fosters communities of open-source software developers, users, and programmers. Open-source ERP systems like Odoo operate under this model.

There is a claim that in recent years, Odoo has gained significant traction in the ERP industry and is often referred to as the 'SAP killer' by many (kerning code,2023) [7]. This assertion serves as a primary motivation for this research. The popularity of proprietary ERP systems stems from their well-documented guidelines and established practices. SAP, for instance, incorporates thousands of best practices into its applications [1]. Open-source ERP systems like Odoo, ERPNext, Dolibarr, ERP5, ADempiere, and Compiere are evolving [1]. However, the global market share of open-source ERP systems has remained at around 3% of the entire ERP market [9]. Odoo accounts for over 50% of the small market share held by open-source ERP systems.

V. SAP

SAP, established in 1972 in Germany by five former IBM engineers, is a world-renowned provider of software for business process management (SAP, 2024) [4]. The company has evolved into a global enterprise with its headquarters in Walldorf, Germany, and over 105,000 employees worldwide (SAP Global Communications 2024). Its ERP software has set the global standard, and now, with SAP S/4HANA, the company is taking ERP to the next level by utilizing in-memory computing to enable cutting-edge technologies like machine learning and artificial intelligence (AI) and manage enormous volumes of data.

SAP S/4HANA, the company's in-house ERP system, replaces the previous, process-driven platform by integrating apps that connect all facets of a business into one intelligent suite on a completely digital platform. With over 100 solutions covering all business operations and the largest cloud portfolio among providers, SAP counted over 230 million cloud users in 2024 [4]. The SAP ERP system provides various business functions with a single source of truth through centralized data management, facilitating better management by providing workers from many departments with simple access to real-time data throughout the company, even for complicated business processes. As a result, companies may increase productivity, streamline processes, improve customer satisfaction, increase operational efficiency, and eventually increase profitability.

Any business may use SAP to collect and handle data on a single platform for anything from manufacturing and customer satisfaction to the sourcing of raw materials. SAP helps businesses analyze and efficiently develop the complete value chain and may be used "on-premise" at the user's site or via the cloud.

SAP HANA is SAP's built an in-memory, column-oriented, relational database management system known as HANA, or "High-Performance Analytic Appliance" [15]. Using the Intel Xeon CPU, the SAP HANA appliance software functions as a flexible, memory-based platform that integrates different SAP software components designed for hardware provided by leading SAP technology partners such as Cisco, Dell, IBM, HP, and Fujitsu. The SAP HANA database, data and lifecycle management apps, support for several industry standard interfaces, and the SAP HANA studio—a user-friendly tool for information modeling and administration—are all included in this appliance's integrated SAP software components. The newest data management platform from SAP is built on top of the SAP HANA database.

The main goal of the SAP HANA database is to provide a strong and flexible platform for different types of queries, such as analytical and transactional ones, with the same data model in an extremely scalable execution environment [12]. Compared to all other ERP data management architectures, SAP HANA offers better and more efficient data access and administration than the traditional SQL database structures used in Odoo. SAP HANA is geared for column-based storage and supports both row-based and column-based storage [15]. Figure 1shows the overview of the HANA database layered architecture.

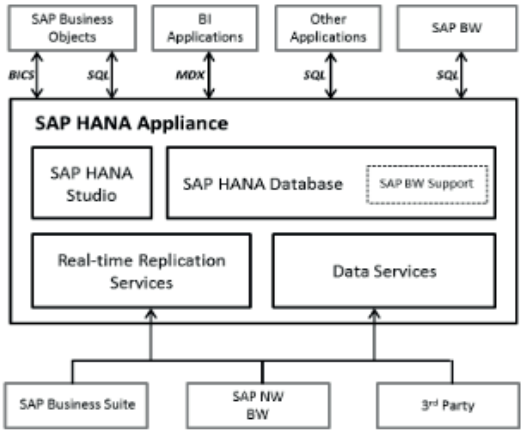

Fig. 1. Overview of the HANA database layered architecture (Source: [12])

The SAP HANA database differs from traditional database systems as it aims to act as a versatile platform supporting various domain-specific languages [12]. The system's core concept is based on a flexible data flow model, where query expressions and scripts are linked to the model, while different physical operators use the same table layer interface for complete record life cycle management. To ensure transactional consistency, logging and data area are utilized to maintain a persistent storage copy of the main memory database [12].

SAP S/4HANA Cloud is specifically designed to cater to the needs of rapidly growing medium to large enterprises across all industries, offering extensive functionality and a high degree of adaptability [13]. The data integration feature in SAP S/4HANA allows seamless integration with SAP and other applications and business processes, surpassing other ERP solutions [14]. This is evidence of SAP's significant impact on the ERP industry. The architecture of SAP S/4HANA facilitates parallelization and integration with open-source technologies like Google Cloud [14]. HANA generates a considerable amount of cache in the database, leading to rapid processing [15]. The efficiency and superior data management capabilities of SAP HANA position it well above open-source ERPs, such as Odoo, in implementation.

The SAP Fiori UI has been created with tiles to provide a user experience similar to that of consumer applications in the corporate software environment. Its main goal is to develop user-friendly, role-specific apps that can be used on different devices.

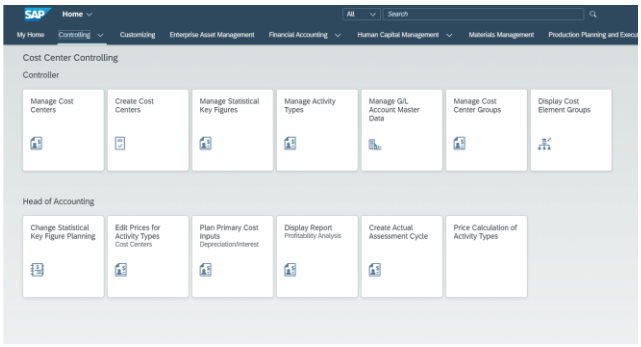

Fig. 1. Example of the SAP Fiori UI

VI. Odoo

Odoo, a collection of open-source business applications, can be tailored to suit any business: CRM, eCommerce, accounting, inventory, point of sale, project management, and more[5]. Its distinguishing feature is its simultaneous ease of use and full integration. Originating in Belgium, its primary aim was to offer businesses a flexible and affordable ERP platform that wouldn't drain their finances.

Odoo ERP is a comprehensive software utilized across the entire company to manage business operations and drive automation. According to Odoo, business software should address complex requirements without being convoluted [7]. Odoo seeks to deliver software that is user-friendly, feature-rich, tightly integrated, and effortless to upgrade, ensuring seamless operation for all businesses and users. As the most widely used open source business software globally, Odoo is free to download and modify [5].

A smooth and welcoming user experience has been constructed to facilitate seamless user adoption. A large community of developers actively maintains Odoo to meet changing customer requirements and introduce new, innovative applications. Odoo's flexibility allows for the addition of apps as the company grows. It offers an adaptable and user-friendly interface designed to streamline business management, providing easy access to various modules and features.

Fig. 2. Example of the Odoo's UI

In the past 18 years, Odoo has expanded to become a prominent provider of management software, with large offices and partners worldwide, serving numerous customers. Odoo is committed to providing top-notch software for businesses to efficiently manage their operations, enabling them to concentrate on running their business [6].

VII. Detailed comparison of SAP and Odoo

In the following a detailed analysis will be provided comparing the two ERPs in terms of different dimensions. We selected some aspects which can be relevant for different companies. Suitability means the business size environment that the ERP can best be deployed to get the best out of it. The development dimension is connected to the program code aspect of the systems. The settings for operating the application are known as hosting preferences. Either the supplier handles all maintenance and availability (as in the case of software as a service models) and the firm pays license costs, or you may download the program for free onto your own server and handle all upkeep and maintenance yourself. Customization means the tailoring the ERP source code to the needs of the business' operations and processes. Data migration refers to moving data and its structure from the current systems to the ERP solution such that its compatible and usable in the ERP. Debugging refers to correcting and troubleshooting issues, errors and logical mistakes that may arise in the ERP source code. Adaptability means having the ERP modified to accommodate new business demands and changing processes and operations.

TABLE I. Comparison of SAP S/4HANA and Odoo

Dimension	***SAP S/4HANA***	***ODOO***
Suitability	Large multinational enterprises with big volume of transactions	Best for Small and Medium sized enterprises
Development	Propietary written in higher level languages like C++, Java and ABAP	Open source written in python
Hosting preferences	Licence fees which exempts server maintenance	No licence fees can even download and install on own servers
Customization & adaptability	Sets requirements for customization as dogma Has more complex structure to adjust the source code to new demands	More flexible to customize Very flexible to adhere to new demands
Data migration	Has backward compatibilty for data transfer with ultimately no coding	Has scripts to ease data transfer
Debugging	Rely on SAP partner or SAP techinical support	Relies on community of developers

It is clear from the detailed comparison table above that with Odoo, companies have control over the ERP code in addition to their main business, but with SAP, they pay and can focus on their core business. A vote akin to the superior ERP does not exist. Every ERP has its strengths and weaknesses. During choosing over the ERP systems, the size of the business, the amount of data handled, the budget, and internal expertise should all be taken into account.

Odoo works well for small and medium-sized businesses with uncomplicated business procedures. Odoo modules' capability of modification, adaptability, and flexibility in the face of a tight budget allows them to handle nearly any typical procedure of work.

SAP S/4HANA is an advanced platform created for large enterprises with intricate workflows. S/4HANA has been developed to handle and store enormous volumes of data. This makes it appropriate for big multinational businesses in a highly competitive market. The company can focus on its primary duties. The ERP obligations such as availability and maintenance are left to SAP at a fee for instance in cloud deployments.

VIII. ERP Cost considerations

Considering the costs associated with open source and proprietary ERP implementations, as outlined in the case, is essential. These costs include acquisition, customization, testing, upgrade, conversion, personal development, unforeseen expenses, time, troubleshooting, and risk. Making well-informed decisions about ERP selection and implementation will lead to success once these costs are thoroughly evaluated and analyzed. When comparing SAP HANA and Odoo, the decision is based on the particular requirements of the company. While larger organizations tend to appreciate SAP HANA's extensive functionality, smaller firms frequently pick Odoo's user-friendly interface and cost-effectiveness. Additionally, the decision is influenced by the budget allocated for ERP implementation and the cost-benefit analysis.

IX. Conclusions

The comparison of the Odoo and SAP ERP systems ultimately shows that the optimal option is contingent upon the particular business requirements, budget, and size. Larger businesses may benefit from SAP's powerful and feature-rich ERP solution, which delivers extensive capability across a variety of business activities. For companies needing worldwide assistance and strong ERP capabilities, its all-inclusive approach is perfect. Conversely, smaller firms may tailor an ERP solution to their own operational requirements with greater flexibility and cost-effectiveness thanks to Odoo's open-source nature and modular architecture. Ultimately, both Odoo and SAP ERP solutions have their strengths and areas of specialization. Businesses embarking on the ERP selection journey should consider their current operations, growth plans, and the total cost of ownership when deciding between Odoo and SAP. By aligning ERP capabilities with business needs, companies can ensure they invest in a system that not only meets their requirements today but can also scale and evolve alongside their future aspirations. The choice between Odoo and SAP is a significant one, paving the way for enhanced efficiency, productivity, and competitive advantage in the dynamic business landscape of 2024

In the end, each of the SAP ERP and Odoo systems has advantages and areas of expertise. When choosing between Odoo and SAP, businesses should take into account their growth goals, present operations, and total cost of ownership. Businesses can make sure they invest in a system that not only fits their needs now but can also grow and change to meet their goals in the future by matching ERP capabilities with company demands. The decision made between Odoo and SAP will have a big impact on productivity, efficiency, and competitive advantage in the ever-changing corporate world.

X. Summary

SAP ERP is a robust, scalable solution with comprehensive functionality, but it comes with a higher cost and complexity. Odoo ERP offers a more affordable, flexible, and user-friendly alternative, but with several limitations in industry-specific solutions and integration capabilities. A large company with complex operations and industry-specific needs should choose SAP S/4HANA with scalability and robustness. For SMEs, Odoo ERP can be a cost-effective solution, with huge flexibility. The choice depends on the requirements of the business, its size, and its budget.

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A Comparative Analysis of S/4HANA and D365 in the Context of AI Capabilities

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***Abstract*— The rapid evolution of artificial intelligence (AI) has significantly impacted Enterprise Resource Planning (ERP) systems. This research aims to compare SAP S/4HANA and Microsoft Dynamics 365, focusing on their respective AI capabilities. By examining the core AI functionalities offered by both platforms, this study seeks to identify strengths, weaknesses, and potential areas for improvement. Key areas of investigation include Natural Language Processing (NLP) and Machine Learning (LM) capabilities.**

Keywords*— *Artificial intelligence (AI), Enterprise Resource Planning (ERP), SAP S/4HANA, Microsoft Dynamics 365, Natural Language Processing (NLP), Machine learning (ML).

I. INTRODUCTION

Artificial Intelligence (AI) has been a growing trend in the development of enterprise resource planning (ERP) systems by organizations looking for greater operational efficiency, more enhanced decision-making and to boost overall company productivity [1] . ERP systems that used to be the core of business operations nowadays are being modernized with AI technologies, for more advanced data analysis, automation, and predictions [2]. The convergence of these two powerful technologies is changing the course of enterprise management, offering it new possibilities that had been previously unobserved. [3].

The premier ERP solutions that have embraced AI are SAP Business Suite 4 SAP HANA (SAP S/4HANA) and Microsoft Dynamics 365 (Microsoft D365). These Tier 1 ERPs are the top-level, most implemented systems in large multinational enterprises around the world and thus set many benchmarks for taking AI right through to have it fully integrated into a modern ERP system. SAP S/4HANA leveraging its, in-memory computing features and instant data analysis [4] along, with Microsoft D365 renowned for its cloud-based design and smooth connectivity with Microsoft offerings provide various AI-powered tools aimed at enhancing business operations [5].

This study aims to compare the AI features integrated into SAP S/4HANA and Microsoft D365. By examining their AI capabilities in Natural Language Processing (NLP) and Machine Learning (ML) this research intends to highlight the strengths, weaknesses, and areas that could be enhanced in both platforms. It is essential for organizations looking to leverage AI to streamline their business operations and stay ahead of the competition to understand these nuances of AI technologies.

II. AI INTEGRATION IN ERP SYSTEMS

The use of intelligence, in ERP systems has attracted interest from both academic and industry circles [6]. As AI technologies advance there is growing research focus on how AI can improve ERP capabilities and add value to businesses [7]. This review explores the changing landscape of AI-powered ERP systems specifically looking at the AI functions, in SAP S/4HANA and Microsoft D365. It analyzes existing studies on AI in ERP breaks down the AI features of these leading platforms and considers the implications of integrating AI into ERP systems.

The converging of AI technologies, with ERP systems is seen as an advancement in business management [6], [7]. Traditionally, ERP systems have been critical for firms that need to coordinate and regulate business processes[8]. However, the increasing complexity of business environments marked by growing data volumes and the need for insights has called for a shift in approach [9].

The integration of AI into ERP systems provides a range of advantages. Firstly, automation driven by AI can simplify tasks allowing human personnel to focus on important tasks [10]. Additionally, AI's capacity to analyze amounts of data enables organizations to uncover insights, improve resource management, and forecast future trends. [11]. Improved decision-making, risk management, and customer contentment are benefits linked with AI-enhanced ERP systems [12] [11].

However, incorporating AI into ERP systems presents its set of obstacles [13]. From challenges, like data quality problems, algorithm refinement, and system compatibility issues to pushback against change worries, about job loss and ethical dilemmas surrounding data privacy and bias in algorithms there are numerous hurdles to overcome [10], [14].

AI technology holds the promise to transform ERP functions in business sectors [10].Take finance for instance where AI-powered automation can simplify accounting tasks identify irregularities and improve cash flow management [15]. The supply chain field can see advantages from AI-driven analytics, demand projection, and inventory enhancement [1] [13] In resources, AI can be used for talent recruitment, performance assessment, and boosting employee involvement [13]. Moreover incorporating AI into customer relationship management systems can enrich customer interactions, with personalized experiences and proactive marketing strategies [18] [16].

While the integration of AI into ERP systems brings potential benefits organizations must adopt a comprehensive approach to implementation [10]. Conquering the challenges and making the most of the advantages that AI brings will be essential, for enterprises aiming to utilize these state-of-the-art technologies [13].

III. Fundamental AI Capabilities in SAP S/4HANA Standard Edition

SAP S/4HANA incorporates cutting-edge AI and machine learning features to transform ERP operations. By leveraging these technologies companies can improve decision making streamline processes and derive insights, from data. This integration enables businesses to handle the challenges of today's business environment with tools, like analytics smart automation and improved decision-making abilities [17].

AI's integration into SAP enables the use of data to predict trends and optimize resource allocation enhancing demand forecasting, inventory management, and predictive maintenance. This leads to improved efficiency and decreased downtime. Additionally, intelligent automation features, like Robotic Process Automation (RPA) and smart document processing tasks can boost accuracy and allow human resources to focus on strategic initiatives [17].

Advanced analytics and NLP enable AI-powered decision support offering real-time insights for decision-making. Moreover, user experience and productivity are boosted by AI and chatbots [17].

Implementing AI in SAP S/4HANA comes with advantages. It is crucial to address obstacles, like data quality, algorithm creation, and organizational preparedness [18]. Ultimately the AI features of SAP S/4HANA empower businesses to excel in the era by enhancing efficiency refining decision-making processes and securing an edge [19].

A. Advanced Machine Learning Techniques

SAP S/4HANA incorporates ML to infuse intelligence into business operations allowing companies to adapt quickly to changing market dynamics. By utilizing the in-memory database capabilities of HANA, SAP S/4HANA effortlessly merges transactional data offering immediate insights and advanced ML features, within the ERP platform.

SAP S/4HANA provides two different methods, for incorporating ML [20]:

1) Embedded Machine Learning

The initial strategy of embedded machine learning is highly effective in situations that require forecasting tasks organizing data and tracking trends. This method works best for applications that use methods, like regression grouping and time series analysis. In these approaches, setup machine learning models are integrated directly into the SAP S/4HANA system. By utilizing the SAP HANA Predictive Analysis Library (PAL) and Automated Predictive Library (APL) data is handled at its source to ensure performance and computational efficiency.

2) Side-by-Side Machine Learning:

SAP S/4HANA also offers another method called side-by-side machine learning, specifically designed for applications that require deep learning capabilities. This approach is ideal for tasks like image analysis and natural language understanding that need resources and the integration of external data sources. To support this method as an extension, ML models are run on the SAP Business Technology Platform (SAP BTP) a cloud-based platform with GPU infrastructure and access to libraries such, as TensorFlow. By delegating these resource tasks to SAP BTP the main SAP S/4HANA system can operate efficiently without being overwhelmed.

The diagram displays the design for integrating machine learning, into the SAP S/4HANA system showcasing both embedded and side-by-side methods.

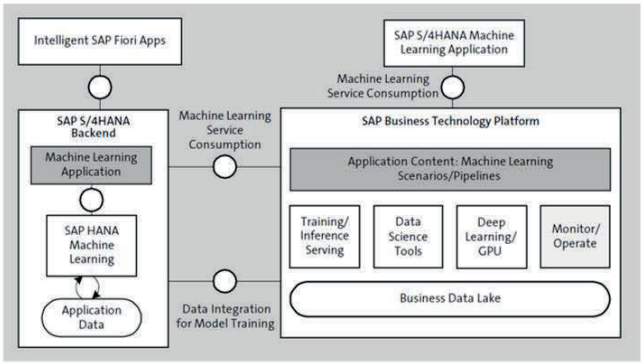

Fig. 1. Embedded & Side-by-Side Machine Learning Predictive Analytics in SAP S/4HANA (Source:[20])

This research solely concentrates on incorporating embedded machine learning.

3) Predictive analytics

SAP S/4HANAs AI features rely on analytics empowering businesses to predict upcoming trends evaluate risks and enhance strategic decision making. Through the analysis of data patterns, ML algorithms can predict customer actions and preferences enabling companies to customize their products and services, with greater accuracy. This results in improved customer happiness, heightened loyalty, and a boost, in profits [21].

SAP S/4HANA utilizes methods to uncover these valuable insights;

a) Regression analysis

b) Classification Algorithms

c) Time Series Analysis

d) Clustering Algorithms

e) Decision Trees and Random Forests

f) Neural Networks

B. Natural Language Processing (NLP) and Its Applications in SAP S4/HANA

Using Natural Language Processing (NLP) greatly enhances the user experience, in SAP S/4HANA by enabling communication through interfaces. NLP bridges the communication barrier, between language and machine understanding empowering users to navigate system features and data without needing technical skills[22].

In SAP S/4HANA NLP is utilized in areas. Conversational query processing allows users to access information and carry out tasks using natural language prompts. This feature enhances user interaction, with the system making it more intuitive and effective. Another valuable application is automated data entry, which simplifies data input and updates through voice commands or text instructions. NLP also improves personalized user experiences by customizing interactions based on preferences, behavior, and context. Furthermore language translation enhances support by translating queries and system responses enhancing the systems accessibility and usability.

When a sales manager uses SAP S/4HANA software and asks about the products sold in the month through natural language processing (NLP) the system understands the question. Provides a simple report, on the best-selling items without requiring complex navigation or technical guidance. This efficient process improves user access and productivity by eliminating steps.

Using these apps NLP boosts user happiness and simplifies tasks. Unleashes the capabilities of SAP S/4HANA [17].

IV. Fundamental AI Capabilities in D365 Standard Edition

Microsoft Dynamics 365 is changing how enterprise resource planning (ERP) works by integrating AI and machine learning (ML) technologies [23]. The latest AI innovations, such, as the launch of D365 Copilot are changing the way companies handle their day-to-day activities boosting efficiency and extracting insights, from data [23] [24] [25].

D365 Copilot employs AI technology to simplify activities, like project organization and reporting minimizing the need, for work and enhancing productivity. This enables professionals to dedicate time to tasks [26], [27].

Essential AI features in D365 include AI, ML, and NLP. These tools support businesses in sectors such as finance, sales, customer service, and supply chain management (SCM) [28], [29]. For example, AI-powered demand prediction, invoice handling, and customer engagement play roles in improving the effectiveness [24], [28].

D365's AI boosts data analysis by offering insights using tools such as Power BI and Excel. This allows users to ask questions in natural language to create useful reports and dashboards [30], [31].

Yet incorporating AI into D365 comes with its set of hurdles. Successful integration and proper data management are essential as issues related to data protection and seamless system incorporation need to be handled [32]. Despite these obstacles, the advancing functionalities of AI hold the potential, for improvements in automation and analytical capabilities establishing D365 as a player, in contemporary ERP solutions [24].

In essence, the incorporation of AI into Microsoft D365 marks a change in ERP technology. Through the utilization of AI resources, businesses can enhance productivity obtain understanding, and handle risks with greater precision. This sets the stage, for expansion and flexibility in an evolving business landscape [33]

A. Natural Language Processing (NLP):

1) Conversational Interface:

Using Copilot simplifies the way people engage with Dynamics 365 by enabling them to input commands through typing or speaking in the language. Whether individuals are searching for information creating reports or finishing a task they can just use language, which enhances the system's user friendliness and reduces the learning curve.

2) Contextual Assistance:

When using Copilots NLP features it can grasp the meaning behind your queries. Offer customized recommendations or assistance. For instance when looking for items, in stock you can explain your requirements using the language of having to know precise product codes or technical specifications.

B. Embedded Machine Learning

Using machine learning, in D365 greatly improves business functions by enhancing forecasting, automating tasks, and enhancing decision-making. In the sector ML powered tools provide budget forecasts, manage cash flow effectively, and offer insights into customer payments making financial planning and collections more efficient. For SCM ML helps optimize demand predictions and manage inventory efficiently to handle disruptions smoothly to ensure operations. Moreover, companies can create ML models using the Power Platform to enhance D365 capabilities leading to increased efficiency and strategic outcomes.

C. AI Applications Across Modules

AI applications can differently support the business processes in the different modules of D365.

In the field of finance, AI plays a role in automating invoice handling forecasting cash flow and delivering financial insights. These tools enable administration and strategic decision-making.

In the area of sales AI boosts the precision of sales predictions streamlines sales procedures and enhances interactions, with customers. These progressions result in informed choices and a more adaptable sales approach.

AI is essential in enhancing customer satisfaction in the realm of customer service through the use of AI assistants and sentiment analysis, which provide personalized and efficient support, to customers.

In the realm of SCM AI contributes to enhancing inventory management, forecasting demand trends, and improving procurement procedures. These advancements lead to economical supply chain activities.

In project management, AI improves areas of project operations such, as planning, implementation, and financial control. These enhancements lead to improved project results and an effective allocation of resources.

V. Comparison of AI in Dynamics 365 and SAP S/4HANA

In this comparison, we thoroughly examine the differences between AI applications in Microsoft D365 and SAP S/4HANA. While both platforms utilize AI to improve business operations, they showcase different approaches and executions. Table 1 demonstrates these differences among some feature dimensions of the two ERPs.

TABLE I. COMPARISON OF AI CAPABILITIES IN MICROSOFT DYNAMICS 365 VS. SAP S/4HANA

Feature	Microsoft D365	SAP S/4HANA
Core AI Capabilities		
Machine Learning	Integrated ML models for anomaly detection, pattern recognition, and process optimization	ML-driven insights for intelligent recommendations, predictive maintenance, and fraud detection.
Predictive Analytics	Utilizing Embedded AI for forecasting demand, inventory levels, and financial trends.	Offers analytics, with AI-generated insights that strongly emphasize scenarios specific, to various industries. Utilizing cutting-edge analytics to enhance supply chain efficiency forecast demand accurately and optimize projections.
Natural Language Processing (NLP)	Interfaced with Copilot allowing users to engage with the system through conversational language inquiries and instructions.	Integrates SAP conversational AI, for incorporating chatbots enabling the processing of natural language queries, in designated workflows.
Automation	Utilizing AI it streamlines activities, like managing budgets handling expenses and forecasting customer payments.	Automation powered by AI is utilized in the finance supply chain and HR sectors to streamline operations on a scale.
Customization	Businesses can customize AI models without needing knowledge through the use of no code AI customization.	Creating AI models allows for a level of customization although it usually demands expertise and specific resources.
Integration and Ecosystem	Integration with Microsoft cloud platform is smooth. There is a wide range of third-party AI solutions available, in the ecosystem.	A close collaboration, with SAPs cloud platform, alongside a range of SAP AI applications.
AI Focus	Applications focused on customer needs and compatibility, with the Microsoft environment.	Supply chain optimization and financial management

In the comparison, between Microsoft D365 and SAP S/4HANA in terms of AI-capabilities it's evident that both platforms provide a range of tools to support business needs. However, they serve different types of companies. Microsoft Dynamics 365 stands out for its easy-to-use and adaptable AI features that can be personalized without expertise. This makes it a great option for enterprises seeking flexibility and versatility in distinct sectors.

SAP S/4HANA, on the side, is designed mainly for corporations needing advanced AI features tailored to specific industries. It excels in providing solutions to address the needs of sectors such as manufacturing, finance, and human resources.

VI. CONCLUSION

The AI and ML in business software solutions are reshaping how companies operate. When comparing SAP S/4HANA and Microsoft D365, it becomes clear that each platform offers AI features designed to meet different organizational requirements. While both systems provide AI-powered solutions the best decision depends on business goals and overall strategies. In essence, effectively incorporating AI and ML into these ERP systems is essential, for fostering innovation improving decision-making processes, and gaining an edge that lasts.

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Reducing waste in warehouse operations through EWM system optimization: A case study of SAP-enabled solutions

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***Abstract*— In today's era of rising environmental concerns and increasing focus on sustainability, organizations across industries are striving to reduce waste and improve efficiency in their operations. This study explores the potential benefits of implementing SAP Extended Warehouse Management (EWM) software to streamline and optimize ware-house processes, thereby resulting in waste reduction. By leveraging SAP EWM's advanced features, such as inventory management, order fulfillment optimization, and real-time visibility, organizations can effectively eliminate unnecessary inventory holding costs, minimize stockouts, and improve overall warehouse productivity. This abstract discusses the key functionalities of SAP EWM that can be utilized to identify and address various waste types, including excess inventory, obsolete stock, material handling inefficiencies, and operational bottlenecks. More specifically, this study investigates how SAP EWM, a comprehensive warehouse management solution, can as-sist in streamlining processes and monitoring inventory levels to minimize wastage of machine oil in warehouses. The significance of integrated technology systems in achieving waste reduction goals, emphasizing the potential benefits of using SAP EWM in warehouse operations, is also highlighted in this research. By embracing SAP EWM as a powerful tool for waste reduction, organizations can significantly enhance warehouse operations, reduce ecological footprints, and contribute to a sustainable future. Finally, this study examines an organization responsible for electricity distribution to reveal the structure and efficiency of systems within this domain, with a particular emphasis on electronic waste management. Furthermore, it explores the implementation of SAP Extended Warehouse Management (EWM) to improve the spatial and quantitative management of waste. The research seeks to understand the interaction of these systems and their contribution to a more effective waste management strategy, thereby optimizing processes in both electricity distribution and electronic waste handling.**

Keywords*— *Sustainability, waste reduction, efficiency, SAP Extended Warehouse Management (EWM), optimization, warehouse processes, real-time visibility, warehouse productivity, waste types, material handling inefficiencies, machine oil, integrated technology systems, ecological footprint, sustainable future, electricity distribution, electronic waste management, waste management strategy, SAP S/4HANA, SAP Waste Management, waste data analysis, forecasting model, KPIs tracking, SAP ERP

I. INTRODUCTION

Environmental protection has come to the world's attention in recent years, and scientists have been emphasizing the need to limit planetary warming. As a result, world leaders from 40 countries participated in the "Leaders Summit on Climate" on April 22 and 23, 2021. The summit was hosted by the President of the United States and held at the White House. The Summit has highlighted how these climate ambitions would create jobs with good incomes, accelerate technological innovation, and help countries in need to adopt the effects of climate change [1]. This eco-friendly mindset to nurture the source of the earth has reached peak momentum so that the organizations feel pressured to start thinking critically in building environmentally friendly business practices. Green supply chain practices [GSCP] are believed to have a potential contribution throughout the entire supply chain process, from suppliers, manufacturers, customers, and until the disposal of the product [2]. According to a recent study, companies need to compete through the implementation of information technology to contribute to the efficiency of the company [3].

Warehouse operations are central entities in competitive supply chains for handling and storing materials. They also are essential structures to enable a smooth product flow in supply chains. Most warehouses have similar distinct activities, including offloading and sorting of goods, put-away activities, picking, and packaging. However, despite the importance of warehouses, many do not operate and perform to their potential because they engage in several non-value-adding activities. In this case, non-value-adding activities contribute neither to warehouse performance nor customer satisfaction, resulting in different types of operational waste. Consequently, identifying and reducing operational waste in warehouses has become a key challenge in increasing the performance of warehouse operations and supply chains. Enterprise Resource Planning (ERP) is one of the information technologies which has a significant influence in enhancing the company's performance [4].

Nowadays, electricity distribution companies face constant pressure to enhance their operations by delivering reliable and high-quality energy at the lowest possible cost and with maximum efficiency.

One of the solutions to this problem is performing supply chains activities using information technology [5]. As a matter of fact, the company's operational performance can be improved by adopting ERP technology, practicing green purchasing, green production, green plant maintenance and more efficient waste management.

Taking all the above into consideration, the main objective of the study is to reduce industrial waste in warehouse operations through an SAP ERP system optimization. More

specifically, this study aims to investigate the benefits and challenges of using SAP's Extended Warehouse Management (EWM) and SAP's Waste Management systems as tools for improving waste management practices in warehouse operations.

II. Literature Review

A. Environmental Impact of a Power Transmision Operator

Power Transmission Operators (PTO) and the environment are seemingly unlikely partners. This is so because all of the high-voltage power transmission lines which emit electromagnetic fields (EMFs), the construction and maintenance of power transmission lines that may require the clearing of land and can disrupt local ecosystems and habitats, and the risk posed to climate change. Pollution is not only caused by these lines but also by substations and the essential cooling and maintenance of autotransformers, which involve significant quantities of lubricants. Environmental issues associated with these Operators include energy consumption, water consumption, wastewater, solid waste and by-products, and emissions to air.

Power Transmission Operators rely on energy to operate and maintain their electrical transmission systems. This energy consumption encompasses the functioning of control centers, equipment, and infrastructure. Additionally, in certain instances, power transmission infrastructure may necessitate water for cooling and other operational purposes. The issue of water consumption is particularly pertinent in regions facing water scarcity challenges. Furthermore, in most cases, transformers are cooled using air conditioners that utilize SF_6 gases, which are classified as greenhouse gases.

Furthermore, the maintenance and construction of transmission lines can generate solid waste, including materials removed during right-of-way clearing. The responsible management and disposal of these waste materials are areas of concern for operators. It is well-recognized that emissions to the atmosphere can emanate from diverse sources, encompassing vehicles and equipment employed in maintenance and construction activities. Emissions can also arise from the operation of backup generators at substations, particularly during power outages.

These considerations underscore the importance of environmentally responsible practices and technologies within the power transmission sector, as well as adherence to regulatory guidelines and environmental standards to minimize their ecological footprint.

It is encouraging to note that numerous operators are progressively adopting environmentally responsible practices and technologies to diminish their environmen-tal impact. These practices are often guided and enforced by regulatory authorities and environmental standards to safeguard both the environment and public health [6].

B. Current status of caprturing PTO Waste Management Information

The increasing focus on eco-friendly and sustainable operational processes has significantly escalated their importance for every business, but even more so for Power Transmission Operators worldwide. This is essential for accurately reflecting and accounting for waste management costs, allowing them to efficiently determine these expenditures and assess their effect on overall profits and environmental impact.

As global power transmission operators increasingly prioritize environmental sustainability, it is becoming a common trend for companies worldwide to address their environmental footprint. This shift towards eco-conscious practices is exemplified by the Greek Power Transmission Operator, which has also recognized the importance of mitigating its environmental impact. Amidst growing concerns about climate change and the detrimental effects of traditional energy production methods, such as greenhouse gas emissions and resource depletion, it is imperative for operators like the Greek company to proactively embrace sustainable initiatives.

The Greek PTO has initiated a project focused on organizing the management systems and procedures for all waste produced as a result of their operations. More specifically, the operator has been diligently executing all necessary actions to establish and activate an Electronic Waste Recording, Evaluation, and Recycling System. Simultaneously, they are ensuring compliance with legislation and updating the required data in the Electronic Waste Registry (EWR). The principal goal of the system, currently in the implementation stage, is to ensure the company's adherence with both national and European legislative mandates concerning appropriate waste management. This is to be attained through diligent recording, monitoring, and evaluation of all determined waste flows, assuring their safe, lawful management, regardless of their ultimate disposal resolution, whether that can be reuse, recycling, recovery, or energy recovery.

Incorporating these efforts with an Enterprise Resource Planning (ERP) system propels the initiative to a whole new level of efficacy. By facilitating a centralized data management approach, an ERP system smoothens the execution of operational and waste management procedures.

C. ERP System Integration

The integration of an ERP system into waste-reduction decisions will provide a transparent view of resource flow within an organisation and access to good information to reveal where waste are created [7]. A waste management system can be integrated with an ERP system through two distinct methods. The first method involves incorporating an additional module directly into the ERP system, thereby enhancing its functionality and providing seamless integration. The second method entails implementing a completely independent waste management system that interfaces with the ERP system through various communication protocols and interfaces. Both approaches aim to streamline operations, improve data accuracy, and enhance overall efficiency in waste management practices.

D. SAP Extended Warehouse Management & SAP Waste Management: Key Features

Reducing waste in a warehouse can be facilitated with the assistance of SAP Extended Warehouse Management (EWM) and its Waste Management process approach. SAP EWM offers a range of features that support waste reduction efforts. For an organization dedicated to electrical power transmission, the responsibility for managing the generation, storage, transportation and disposing of materials deemed to be waste relevant [8].

For an organization dedicated to electrical power transmission, the implementation of SAP EWM yields tailored benefits essential for its operational excellence. Initially, SAP EWM provides robust support for the storage of hazardous materials, ensuring strict adherence to safety regulations and mitigating the potential for accidents or environmental incidents. Through precise tracking and monitoring capabilities, SAP EWM enhances safety protocols, effectively managing these critical assets to sustain operational continuity and prevent disruptions.

Furthermore, SAP EWM optimizes the management of maintenance items, subproducts, and waste generation—integral facets of power transmission operations. By streamlining inventory processes, the system ensures the availability of essential maintenance items, minimizing downtime and bolstering equipment reliability. Addi-tionally, it facilitates meticulous tracking and utilization of subproducts, identifying avenues for recycling or repurposing to maximize resource efficiency and reduce waste output, thereby aligning with sustainability imperatives.

Moreover, SAP EWM elevates the handling of waste storage and shipping, tackling the complexities associated with regulatory compliance and environmental stewardship. With its advanced inventory management functionalities, SAP EWM enables organizations to methodically segregate, store, and label various waste types, ensuring secure handling and mitigating environmental risks. By facilitating compliance with legal mandates and industry standards for waste transportation, SAP EWM contributes to environmental responsibility, diminishing the ecological footprint of power transmission endeavors. In essence, SAP EWM empowers electrical power transmission entities to fortify safety measures, optimize resource utilization, and champion environmental sustainability, ultimately bolstering the reliability and efficiency of power distribution endeavors.

Additionally, SAP EWM ensures comprehensive tracking and traceability of waste throughout the supply chain, from its inception to its ultimate disposal or recycling.

One leading technology in this sector is the RFID (Radio Frequency Identifica-tion) scanners. SAP EWM can further support the organization in reducing the level of waste through the use of RFID scanners, which can be executed on mobile or handheld devices, enabling real-time tracking and monitoring of waste movement and inventory levels. This enhanced visibility facilitates proactive decision-making, allowing the organization to identify inefficiencies, minimize waste, and optimize resource utilization throughout the supply chain. Additionally, RFID technology enhances accuracy and efficiency in waste management processes, automating data capture and reducing manual errors associated with traditional inventory management methods [9].

This end-to-end visibility not only ensures regulatory compliance and adherence to environmental standards but also empowers organizations with insights to enhance operational efficiency and sustainability. Through specialized inventory management features, SAP EWM facilitates proper handling, labeling, and storage of waste materials, minimizing risks of contamination and ensuring safety within storage facilities. Complemented by robust reporting and analytics capabilities, the system empowers organizations to analyze waste generation patterns, identify optimization opportunities, and make informed decisions to drive continuous improvement in waste management practices.

III. Problem Description

In the modern era, there was a genuine need for the products and services to be increased in this new market. Industries have to uprise their products and goods due to a dramatically increasing demand. In order this aim to be achieved, the industry players are impelled to alter the traditional ways of their production. Globalized workforces and supply chains have raised environmental strains and associated business obligations. The rise of new global powerhouses has escalated the rivalry for natural resources, thereby introducing a geopolitical perspective to the concept of sustainability [10]. The notion of sustainability not only pervades the itineraries of governments and organizations, but also the mission and vision of the educational and research programs worldwide [11].

Despite the existence of some earlier precursors, these concepts gained formal recognition and began to crystallize in the 1980s. Three interconnected objectives re-flect the provided definition of sustainability development: environmental, economic, and social [12]. This is commonly referred as the Triple Bottom Line [13]. This approach suggests that besides economic performance, corporations require to engage in activities that positively affect the environment and the society. Nowadays, a growing multitude of consumers have demonstrated an inclination towards sustainable products and services and placing dependence on companies that adhere to progressive sustainability practices.

Corporations are implored to enhance their flexibility to promptly adapt and respond to market alterations, owing to the rapidly evolving business strategies and the dynamic global business environment. Among the catalysts instigating changes, the demands for corporate responsibility and sustainability are becoming ever imperative.

A. The Role of ERP Systems in Sustainable Business Growth

There is a noticeable upsurge in the number of organizations progressively integrating contemporaneous Information Technology (IT) applications and products into their operational processes. This is possibly sensible as such technologies help organizations to perform business operations effectively, provide strategic advantages and have a potential to lead organizations towards growth and innovation [14].

It is well defined that numerous IT solutions are available in the market. Although, during this study, the EWM system was proposed to be implemented to the Greek PTO. This system was selected, among others, to efficiently manage the stock and the waste materials, alongside activating its Waste Management module (EHS-SUS-WA).

B. ERP Systems in Sustainable Decision-Making for Waste Management

As a business strives for profit growth and new business value creation, it also aspires to achieve sustainability and development. Decision-makers with immediate access to data from an ERP system can efficiently manage and allocate enterprise resources by gaining insights into business profitability and environmental impacts. This is facilitated by KPIs, such as measurements of environmental permitting

compliance for projects and activities, adherence to permitting legislation, and compliance with Electronic Waste Register (EWR) requirements.

This advantage facilitates competitiveness, stimulates cost-reduction initiatives and aligns profit generation with societal impacts. It leads to the internalization of social and environmental factors and institutionalizes sustainability-oriented leadership via the ERP system.

Enterprise Resource Planning (ERP) systems provide an essential resource for waste management by harmonizing processes for optimal efficiency and sustainability. Key features such as inventory management, supply chain integration, and material requirements planning facilitate the reduction of waste. These systems ensure invento-ry levels are maintained accurately, materials are procured timely, and appropriate quantities are produced. ERP systems also enhance quality control, demand forecast-ing, and financial management, reducing waste caused by defects, overproduction, and ineffective resource allocation.

IV. Methodology

Even with significant advances in decreasing pollution from the electric power industry, power plants that use fossil fuels are still major contributors to air, water, and land pollution affecting communities across the globe [15]. A comprehension of the various elements involved, and their environmental consequences is needed to assess the pollution effect from activities such as power production installations. Electricity generation & distribution facilities, particularly those dependent on fossil fuels, have a varied array of environmental implications, contributing to air and water contamination, soil degradation, destruction of habitats, and global warming.

To moderate these effects, the focus is shifting towards adopting alternative electricity production methods such as wind and solar power, which generate minimal pollutants and inflict significantly less environmental harm. Nevertheless, the shift towards these renewable energy sources needs to be meticulously steered to alleviate potential environmental repercussions while maintaining a dependable electricity supply. Although, electricity transmission is unavoidable, capturing and mitigating associated pollution is critical for a cleaner energy grid. PTOs operations can be optimized to minimize their environmental footprint through the implementation of pollution capture technologies and essential reduction strategies.

A. Legal Requirements Valid for EU & Local Industries: Pollutant & Dangerous Goods

Predicated on the tenets of precaution, prevention, pollution mitigation at its genesis, and the 'polluter pays' doctrine, the European environment policy seeks to address an array of multifaceted ecological predicaments. The European Union (EU) grapples with intricate environmental dilemmas that span from climate variations and biodiversity decline to resource scarcity and pollution. Recent developments have seen environmental policy gaining a pivotal role within EU legislation. The Commission has instigated the implementation of the European Green Deal (2019), positioning it as the principal impetus behind the EU's economic augmentation strategy [16]. The European Union is competent to act in all areas of environment policy, such as air and water pollution, waste management and climate change.

B. Detection of the Waste Generated by a Warehouse of electricity Transportation Company

The effective management of waste within warehouse facilities of electricity transportation company plays a pivotal role in upholding environmental sustainability and regulatory adherence. With a multitude of contributors, spanning from maintenance tasks on plant machinery to the disposal of office and facility waste, a comprehensive strategy is indispensable for handling diverse waste streams efficiently. From waste oils and hazardous material spills to electronic waste and municipal refuse, each category presents unique chal-lenges that require specialized management techniques. Understanding these distinct waste types and implementing appropriate disposal methods are imperative for maintaining operational efficiency and mitigating environmental impact.

Herein lies an exploration of the primary waste streams identified within the specific warehouse environments:

a) Waste oils resulting from maintenance activities on the plant's equipment

b) Liquid waste spills originating from waste storage areas are gathered in containment basins

c) Used batteries extracted from the plant's motorized equipment

d) Used tires from the plant's motorized equipment, for instance forklifts

e) Waste originating from Electronical and Electronic Equipment (WEEE)

V. Implementation

A. Registration Steps of Waste by the Responsible Teams in the ERP System

The subsequent chapters will delve into the examination of the registration steps in-volved in waste management within a warehouse setting in an SAP ERP environment. Each of these steps encompasses a distinct methodology consistently implemented by the responsible team.

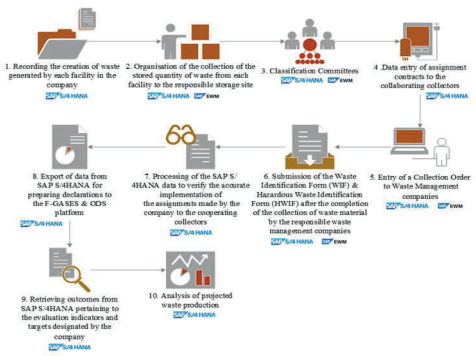

Fig. 1. High-Level Overview Workflow

1) Step 1: Recording the creation of waste generated by each facility in the company. The primary objective is to accurately record the generation of waste from each facility. This initiative is undertaken alongside enhancements to Work Order management, ensuring a seamless progression from task inception to finalization. The impact of this step is evident in the monitoring of waste quantities stored per facility to streamline waste collection planning. The

application may incorporate guidelines for setting maximum storage limits for each type of waste at each facility. If these quantities exceed the specified limits, an alert is generated.

2) Step 2: Organisation of the collection of the stored quantity of waste from each facility to the responsible storage site. In this process, within SAP S/4HANA, predefined thresholds will be set for the quantity of waste per category and materials earmarked for inspection. Upon surpassing these thresholds, it becomes incumbent upon the Administration to commence the transfer procedure from the pertinent facility to the responsible storage facilities, using the SAP EWM. In accordance with software specifications, an alarm will be activated upon reaching these predefined thresholds, thereby indicating the necessity for immediate action.

3) Step 3: Classification Committee. This identification process serves to reduce errors in distinguishing between materials designated for disposal as waste and those suitable for reuse as usable products. Furthermore, it aids in determining the quantity slated for disposal, thereby facilitating the organization of recycling efforts by companies and enabling forecasts regarding the volume of waste expected within a specific timeframe. As a result, with the assistance of SAP EWM, Classification Committees wield the authority to categorize materials as waste for disposal or as candidates for reuse, thus integrating them back into operational processes.

4) Step 4: Data entry of assignment contracts to the collaborating collectors. The Department responsible for tendering evaluates the EWC codes and associated waste quantities for each project. Once the tendering process concludes and contracts are signed by the designated collectors, they are then transferred to the Department tasked with entering contract data into the ERP system. Then the user accountable for data entry, which process is facilitated within the SAP S/4HANA, must provide the appropriate inputs for each EWC code pertaining to hazardous waste, non-hazardous waste, and F-GASES/SF_6, such as:

a) Contact number with the PTO and its expiration date.

b) Company code managing the waste disposal.

c) Company code managing the waste disposal from the Electronic Waste Registry (EWR).

d) Quantity of watse to be disposed.

e) Expiration date of the responsible collecor’s licence.

f) Collector’s ADR4 driver names & licences.

g) Expiration date of collector’s Intermediary Liability policy.

h) Fee per unit of weight or charge per unit of weight.

5) Step 5: Enrty of a Collection Order to Waste Management companies. The primary objective of this step is to notify the companies responsible for the collection and dis-posal of the waste. This is accomplised following the 3 sub-steps:

a) Registration of Waste companies in SAP S/4HANA

b) Delivery coordinaor records the Colletion Order in SAP EWM

c) The coordinator forwards the Collecction Order to the associated companies to begin the collection process.

6) Step 6: Submission of the Waste Identification Form (WIF) & Hazardous Waste Identification Form (HWIF) after the completion of the collection of waste material by the responsible waste management companies. The main objective of this step is to systematically submit information concerning the disposal of waste, by the contractor, immediately after the collection of this type of material. In more detail the contarctor (associate collector) has already collected the waste and transferred it to the designated area where the disposal procedure takes place. Immediately after loading and transporting the waste material, the contractor accesses the SAP EWM using the unique Collection Order code generated by the company during the collection process. Automatically, data pertaining to the waste material are recorded in the system, such as the EWR code and its detail, the field where the drivers and ADRs declared will be shown to select who made the collection and the facility from which the collection is being made. At that point the contractor should enter the following data regarding the waste:

a) The quantity/weight of waste without packaging

b) The details (EWR code) of the facility where the waste was delivered

c) Waste management operation (R & D)

These records will constitute the data for the submission of the report of each warehouse to the EWR.

7) Step 7: Processing of the SAP S/4HANA data to verify the accurate implementation of the assignments determined by the company to the cooperating collectors. The primary objective of this stage is to confirm the accuracy of data en-try conducted within SAP S/4AHNA by the designated contractor responsible for waste material collection. Additionally, it emphasizes the system's capability to issue notifications and alarms in case any oversight of predetermined waste management rules occur. Lastly, it underscores the ERP system's proficiency in generating relevant reports for uploading to the EWR, inclusive of all necessary specific information.

8) Step 8: Export of data from SAP S/4HANA for preparing declarations to the F-GASES & ODS platform. The advantage of producing these data reports via SAP S/4HANA is the optimization of the declaration submission process to the F-GASES & ODS platform for the company. By centralizing all pertinent data within the ERP system, the company can ensure precision, thoroughness, and punctuality in their submissions. This not only aids in adhering to regulatory obligations, but also enhances operational efficiency by diminishing manual labor and potential inaccuracies linked to manual data input. Furthermore, the availability of comprehensive reports supports improved monitoring, analysis, and decision-making concerning machine maintenance and compliance with environmental regulations.

9) Step 9: Retrieving outcomes from SAP S/4HANA pertaining to the evaluation indicators and targets designated by the company. The extraction of results from SAP S/4HANA involves retrieving data related to the

evaluation indicators and targets chosen by the company. This process entails accessing pertinent information within the System, focusing on the specific metrics and objectives set by the company for evaluation purposes. By extracting these results, the company gains insights into its performance against predetermined benchmarks, facilitating informed decision-making and strategic planning.

10) Step 10: Analysis of projected waste production in the SAP S/4HANA environment. Analyzing projected waste production not only aids in maintaining regulatory compliance but also enhances operational efficiency and supports sustainable practices. This process involves a meticulous five-step approach to ensure accurate forecasting and strategic decision-making. The following steps detail the comprehensive methodology for analyzing projected waste production, from data submission and extraction to historical analysis and strategic forecasting.

a) Data submission into SAP S/4HANA regarding the quantity of waste generated and handed to the contractor for disposal

b) Data submission into SAP S/4HANA regarding the actual quantity of waste were disposed of by the contractor

c) Data gathering regarding the production and disposal history of the waste generated

d) Analyze the historical data & setting up forecasting models

e) Examine the waste forecasting reports & KPIs to enable strategic decision-making

By following this structured approach analyzing projected waste production en-sures that companies can effectively manage their waste, enhance sustainability, and make informed decisions that support long-term environmental and operational goals, based on a forecasting analysis and reports in SAP Waste Management. As a result, this could lead to a more efficient waste handling and better environmental compliance.

CONCLUSION

Organizations are progressively realizing the importance of information systems to support sustainability initiatives. They need to align between their sustainability strategy and information system strategy. PTOs are focusing on effective practices, adopting related techniques and establishing information systems that provide comprehensive solutions for waste management. By aligning waste management with their broader sustainability goals, these companies promote a holistic approach to environmental sustainability resource efficiency. Waste management in electricity distribution is a necessary practice for the protection of the environment and the sustainable development of energy companies. However, organizations still have problems in collecting, integrating and reporting sustainability information. To solve this problem, the organizations need to adopt an integrated information system, such as SAP ERP system. The implementation of SAP Waste Management (WM) and EWM systems offers integrated solutions for waste management. The first one integrates all waste management processes into a single system, providing tools for monitoring and generating compliance reports, while the second one offers solutions for efficient waste management in warehouses, facilitating optimal material flow and inventory management. By implementing these SAP ERP systems, companies can automate processes, increase efficiency, ensure compliance with regulations, export related reports and measure useful KPIs to leverage strategy decisions.

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Teaching SAP Analytics Cloud (SAC): Benefits and Challenges

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***Abstract*—Integrating SAP Analytics Cloud into the curriculum is essential for business, data science, and information technology students. SAC provides a comprehensive enabling platform for data visualization, predictive analytics, and business intelligence skills that will be demanded from students in the future. Teaching SAC with University Competence Center Magdeburg's instructional resources provides advantages in several areas: industry-relevant skills, enhanced data visualization, real-world business scenarios, and cloud-based access. The challenges include maintaining up-to-date content, a steep learning curve, insufficient focus on advanced features, and lacking project-based, real-world data applications. Possible improvements this study proposes include updating the teaching materials, integrating more PBL opportunities, and real-world data analysis into the course, and enhancing collaborative learning experiences.**

***Keywords*— SAP Analytics Cloud (SAC), University Competence Center (UCC) Magdeburg, Project-Based Learning (PBL), Benefits, Challenges**

I. INTRODUCTION

With data analytics gaining more and more importance in all spheres of life, incorporating high-class advanced data analytics tools into curricula is crucial in contemporary higher education, especially in business, data science, and information technology. One such tool is SAP Analytics Cloud, which will give the students substantial experience in data visualization, predictive analytics, and business intelligence, affording them invaluable experience working with state-of-the-art technologies highly in demand across multiple industries. As the digital economy continues to evolve, there is a growing need to analyze and interpret big, complex data [1]; thus, it has become an important core competency among business professionals. Thus, this sets demand to effectively teach SAC and prepare students for the demands in the workplace they will face sooner or later.

In that regard, the demand for pedagogical strategy has concentrated on Project-Based Learning. Indeed, the PBL approach highlights real-world applications and experiential learning to enable students to deal with complex projects representative of scenarios in the industry itself [2]. With PBL, critical thinking, problem-solving, and collaborative skills are developed; hence, it prepares students for their future professional challenges effectively [3]. By applying the PBL model, students will learn the theoretical aspects of SAC and gain practical experience by working on real-world projects, enhancing their ability to apply what they have learned to business contexts. [4], emphases how important it is to align software engineering education with market-driven industry needs, including developing critical skills such as creativity, critical thinking, collaborative decision-making, and communication (C4 skills).

University SAP-related programs greatly benefited from instruction resources provided through UCC Magdeburg, including cloud infrastructure and teaching materials for facilitating practical and skill-oriented learning. Meanwhile, a few obstacles must be overcome before SAC can fully support the development of

industry-relevant student skills. Research confirms that educational methodologies should be updated continuously according to the evolution of technologies, especially in fields that show the most rapid growth, like data analytics [5]. In this respect, adaptive teaching strategies that combine PBL and provide regularly updated flexible learning material will better enable students to master SAC and develop the relevant critical competencies in demand today within modern data-intensive industries.

This article explores the benefits and shortcomings of UCC Magdeburg's materials for teaching SAC, considering the need for PBL strategies. The study hopes to put forward actionable recommendations that enhance the effectiveness of instructors and optimize learning outcomes for students to provide them with the required skills and knowledge for success in a digitally changing world.

II. Benefits of Teaching SAC with UCC Magdeburg Materials

With each passing day, industries are laying more emphasis on data-driven decision-making processes, and hence, the integration of SAP Analytics Cloud into academic curricula has grown in importance. Teaching SAC provides a set of critical skills highly sought after in the global workforce.

A. Development of Industry-Relevant Skills

The first of the benefits involved in teaching SAC is that this tool imparts industry-relevant skills in data analytics, business intelligence, and performance management. Various companies are moving to a data-driven model requiring professionals with expertise in data visualization, predictive analytics, and reporting [6]. In this respect, SAC makes these functions much more accessible for students, who can understand and present better meanings of complex data. In this manner, a deep understanding of the functionality of SAC adds genuine value for students later in their professional lives. Research indicates that practical experience with real-world analytics tools enhances data literacy and the ability of students to engage in evidence-based decision-making [7,8], among the most valued skills by employers in finance, marketing, and operations. The fact that the software is cloud-based also reflects the nature of modern business, where many businesses operate on cloud platforms for dissemination and collaboration.

B. Empower Data Interpretation and Visualization

The focus on data visualization at SAC will be helpful for students who must learn how to take raw data and turn it into actionable insights. In SAC, different visualization tools can show students how presenting their data in ways that are more visually appealing will allow them to be better interpreters themselves or make better interpretations available to stakeholders by creating dynamic dashboards and reports. As stated in [9], visualization is one of the most crucial components in the education process of data science as it enables users to see behavioral trends, patterns, and anomalies that would otherwise be indistinguishable from raw data. In addition, SAC can enhance student’s learning by complementing other data sources and systems like SAP HANA or Microsoft Excel, which prepares them for the tools they will have to use in the real business world. The focus on visual storytelling communication is quite relevant for business program students, as they will learn how to present complex data in a form that can be easily understood by decision-makers.

The major benefits also include Case Study-Based Learning (to develop problem-solving skills), Alignment with the SAP Ecosystem, Cloud-based access, and collaborative learning. These advantages set the foundation for students to pursue lucrative careers in

analytics and business intelligence by ensuring that academic content stays abreast with current industry trends

III. Critical Issues Arising in the Teaching of SAC with UCC Magdeburg Materials

While there are undeniable benefits, the teaching of SAC also poses some challenges that the educator must handle for effective integration; these are discussed in detail below.

A. Lack of real-world context

Learning materials are either too theoretical or focused on purely technical functionalities of SAC, without demonstrating how those apply in a real business context. Students cannot see the practical relevance of what they learn. This is also extended by the assessments, which focus too much on theoretical knowledge or technical skills and less on students' ability to solve real-world business problems using SAC.

B. Limited project-based learning

The course material provided for SAC by UCC Magdeburg is developed to give the student a structured learning experience but mainly on the technical usage of SAC in data analysis, data visualization, and predictive analytics. While the materials provide step-by-step instructions for performing tasks in SAC, they lack opportunities for students to explore the tool independently or work on open-ended projects which will foster problem-solving, critical thinking, and technical confidence. Students are denied opportunities to work on realistic projects, such as creating dashboards, developing predictive models, or analyzing datasets.

C. Insufficient Focus on Advanced Features

Most courses concentrate too much or entirely on the basics (reporting & dashboards) and do not delve into SAC more deep, predictive planning; wrangling; and machine learning integrations. The available features are so much less that students cannot learn the advanced concepts, that play a crucial role in their industry success.

D. Inadequate Collaborative Learning

The materials focus on individual learning tasks rather than encouraging collaboration and teamwork, which are key skills in business analytics roles. Students must learn to collaborate on analytics projects and share insights.

E. Difficulty Keeping Content Up-to-Date

Given the rapid pace of technology development, teaching materials can quickly become outdated, meaning that students may not be learning the latest features and updates in SAC. There have been situations where the features and steps shown in the teaching guide are incompatible with what is present in SAC.

F. Limited Preparation for Certification

The teaching materials do not provide enough guidance for students interested in obtaining SAP certifications, which are highly valuable for career advancement. Consequently, adding bonus modules in conjunction with our certification-centric content that will prepare students to get official SAP SAC certification is relevant. Some examples are practice exams, certification roadmap guides, and relevant workshops.

G. No Real-Time Data for Analysis

The students or even the teachers are not able to get access to real-time as well as relatable datasets which would serve better under their educational and professional circumstances resulting in an out-of-context type education teaching. If UCC Magdeburg could foster partnerships with local businesses or industry to provide access to real-world datasets or use

publicly available datasets for student projects. This will provide students with more authentic data analysis experiences and help bridge the gap between classroom learning and real-world application.

IV. Conclusion

Teaching SAP Analytics Cloud using materials from UCC Magdeburg offers the following advantages: relevance of the received skills to the industry, improvement of data visualization, and practical training. However, based on the above-mentioned points, it is crucial to overcome such disadvantages as outdated content, limited real-life context, insufficient focus on advanced features, and no collaborative learning to substantially improve SAC instruction. These will be further realized with the usage of more real-world-based data sets, project-based learning, and updated materials. It is by surmounting these hurdles that educators can work on improving student learning outcomes and prepare them for better meeting emerging needs in the data-driven workforce.

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Combining SAP with IoT for Real-Time Data Quality Monitoring

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***Abstract*—Today, data quality and completeness are essential for making smart decisions and enhancing the efficiency of organizations, as traditional approaches to data quality management have been insufficient to achieve real-time visibility and address emerging shortcomings quickly. This paper demonstrates how to implement IoT-based data quality monitoring in SAP systems. With IoT sensors integrated into the SAP system, data will continuously emanate from production lines, supply chains, and operational equipment, while information flows seamlessly. Additionally, real-time data streams will ensure the remediation of any detected anomalies, checked for accuracy, and integrity within the SAP environment in real-time. While such an approach ensures greater accuracy of data, it also provides valuable insight into areas that will lead to proactive measures on data quality and hence ensure that corrections in data are effected well before data can start impacting business outcomes. Secondly, IoT integration improves collaboration among various departments through a single view of data that leads to better-informed decisions at all levels. Such real-time access and analyses of data support a culture of continuous improvement and agility, and enable companies to respond with urgency to fluctuating operational conditions and market demand. Data quality processes, if automated, contribute to more operational efficiency and help an organization reduce a number of risks relating to compliance and regulatory issues. Integration of IoT with the SAP system will, therefore, be in a position to ensure data integrity and responsiveness at an unparalleled level, thereby helping smooth operation and improving overall strategic performance. In other words, such organizations take a competitive advantage in the evolving digital environment.**

***Keywords*—Data quality, SAP, IOT, Sensors, Monitoring, Business, Real-time.**

I. Introduction

SAP systems are renowned for their ability to manage extensive and complex data across various business functions. However, conventional data quality management practices often rely on manual processes and so on, which may not provide comprehensive solutions for data issues [1] [2]. Incomplete (missing) or poor-quality data can lead to operational inefficiencies and poor decision-making. Ensuring complete data quality in real-time is critical to maintaining the integrity of business operations [3]. IoT sensors introduce the opportunity for an improved quality management of data through capturing in real time and continuously from diverse operational sources [4]. Integration with SAP systems allow for the real-time and proactive monitoring of the data at the time of capture to quickly detect anomalies [5] [6].

Besides, the imperatives of digital transformation strategies by organizations create a compulsion for an adequate governance framework of data. IoT can help businesses reduce latency in conventional data processing methods. This capability, other than enhancing the responsiveness of operations, helps in fostering a data-driven culture within organizations. Therefore, it paves the avenues for predictive analytics to warn against any potential issues before they are blown out of proportion. This could also help increase viable competitive advantage in sustainability by fostering better decision-making. The paper presents an investigation of how synergy between SAP systems and IoT sensors enables real-time monitoring of data quality for improvement in business performance. Accompanied by the integration of IoT data into SAP systems, this presents a more accurate detection of anomalies while building deep insights in knowing operational trends. IoT integration supports an organization in real-time that dynamically fine-tune its processes for continuous improvement. In addition, it can give a view since data taken is from various sources and therefore can present a view that is very holistic of operations; hence, strategic planning will be better informed. Enhanced collaboration between departments involves unified data visibility to ensure that everyone has access to the same reliable information. With integration of IoT and SAP system, there is greater inspiration to be agile in responding to changes within the market for the improvement of customer satisfaction through timely service delivery. data quality management allows organizations to minimize compliance and regulatory risks. It therefore helps in facilitating the overarching objective of attaining operational excellence, with a view to realizing sustainable business growth and innovation.

II. Literature Review

In this section, we provide an overview of key concepts and technologies relevant to the integration of SAP systems with IoT for real-time data monitoring, various approaches are examined to highlight their impact on data quality and business performance.

Authors in [7] propose a real-time health monitoring platform using the SAP HANA platform for data analysis from IoT devices and wearables. By providing an in-memory computing capability, SAP HANA can process huge sets of health data, such as ECGs, in real time. This approach enables early detection of health conditions, especially for elderly care and chronic disease management. The integration of SAP HANA into healthcare systems realizes better patient outcomes and decreases the burden on healthcare infrastructure. In [8], the authors address the problem of fault diagnosis and prediction in process industry using IoT data. They developed the solution based on IoT technologies offered by SAP. First, the methodology extracts the casual relationships from the sensor data without a priori knowledge of the system. Detection of faults in the devices takes place with real-time monitoring, and the discovered relationships are used for fault prediction of other devices. This predictive capability enables proactive maintenance to have operators informed in due time. The effectiveness of the solution is illustrated by its application in the field with an industry partner. Authors of [9] describe different possibilities of IoT technologies in order to monitor the status of pipelines, detect problems in infrastructure, and obtain key data on the capacity and location within an Oil & Gas industry. They present the usage of SAP HANA Cloud Internet of Things services, which can gather such information and analyze it for better access and integration. The underlying thesis here is that such deployment can reduce the collection time for data drastically, thereby making continuous pipe condition awareness possible. Therefore, the industry will better make decisions based on thorough data analyses. In [10], the key factors affecting KPIs in BPM of logistics businesses are underlined, focusing on the role that inventory management and manufacturing processes play. They go further to state that the data obtained from these two areas are captured and updated on SAP ERP systems; these are integrated supply chain functions. From traditional logistics, the shift to an internet economy has transformed it into E-logistics, enhanced through IoT for real-time updates. This development will enable the management to make informed decisions on time and cost savings, hence operational efficiency. The authors in [11] take a closer look at HANA Smart Business apps, which grant users real-time analysis of strategic and operational KPIs to make better decisions. They mentioned that the capability of SAP HANA to process data in real time makes it perfect for IoT applications. The needed tools to exploit this feature are given by the SAP HANA Cloud Platform. This chapter explains how a UI5 application is created and integrated with various sensors using a Raspberry Pi, with SAP HANA acting as the application-to-sensor connector.

III. NOVEL APPROACH

This study focuses on how the SAP systems would integrate with IoT sensors in real time for monitoring data quality. The continuous data is acquired by IoT sensors and fed into the SAP systems, where the occurrence of abnormalities can be detected at speed and the assurance that the decision-makers will always have updated information. Our approach embeds real-time validation into the robust data management framework provided by SAP to enhance its accuracy and reliability.

The solutions, therefore, support an organization in reducing dependence on manual efforts to verify data and ensure qualitatively better decisions based on the validation of data. This dynamic solution reduces not just errors but also puts organizations in an active state as far as data quality management is concerned. What's more, our research evaluates the effectiveness of the existing methods that tie IoT sensors into the SAP ecosystem for seamless, continued monitoring of data quality.

With such integration also comes the very important aspect of data integrity, as discrepancies are caught and dealt with in real-time. Besides, the framework we have proposed makes it possible for organizations to institute a culture of fact-based decision making that puts them at an advantage of responding swiftly to operational challenges as well as changes in the market. Our contribution with this respect contributes to the general strategy of how to leverage IoT technology within SAP systems in business performance improvement as well as enhanced operational efficiency.

IV. ARCHITECTURE OF THE PROPOSED APPROACH

This section outlines the architectural framework that integrates IoT sensors with SAP systems for real-time data quality monitoring. It details the key components, including data acquisition modules, SAP HANA for processing, highlighting how they interact to ensure data accuracy and reliability.

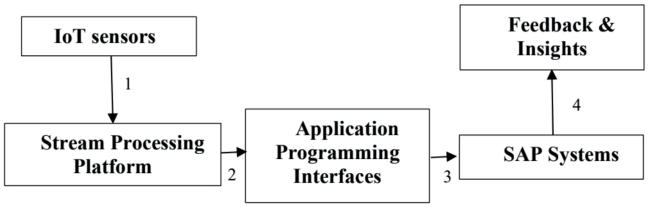

Fig. 1. The typical stages involved in the model for Data Quality Monitoring.

Figure 1 illustrates the architecture for SAP integration with IoT sensors technology for real-time monitoring of data quality.

1) **Collection and Transmission of Data:** IoT sensors are deployed at the point of critical impact in the operational environment such as manufacturing equipment, these sensors constantly detect and process various parameters, each sensor produces streams of real time data that are forwarded to a stream processing platform.
2) **Data Aggregation and Preprocessing:** The data sent from IoT sensors moves to a stream processing platform,

where it undergoes preprocessing and converting it into a standardized format compatible with SAP systems.

3) **Integration with SAP:** The preprocessed data is integrated into SAP systems using APIs (SAP Cloud Platform Integration (CPI)). This integration ensures a smooth flow of data into SAP's data management modules, such as SAP ERP or SAP HANA. Real-time validation rules within SAP are applied to detect abnormalities, inconsistencies, or missing values as the data is ingested. This immediate validation helps quickly identify and resolve data quality issues, maintaining the integrity of the information used for business processes.
4) **Real-Time Monitoring and Feedback:** Once validated, the data is used for real-time monitoring and analysis. The system generates alerts if any issues are detected and provides actionable insights through SAP's analytics and reporting modules.

A. Component Overview

The architecture of the proposed approach consists of a series of key components that work in tandem to enable real-time monitoring of data quality, integrating IoT sensors with SAP systems. Each component in this regard plays a very vital role in ensuring effective data collection, processing, and management. The main building blocks of the architecture are as follows:

- **IoT Sensors:** IoT sensors are deployed on critical operation points such as the production line and nodes in the supply chain for continuous data acquisition concerning various parameters related to temperature, pressure, and humidity. These sensors will stream data in real-time, which is highly useful in monitoring condition-based assets and spotting anomalies just in time.
- **Data Acquisition Modules:** These modules help in primary capturing from the IoT sensors and ensure that such information is relayed to the processing platform. They provide the first contact point for data, hence ensuring that the information is well formatted and sent securely and efficiently to the next stage.
- **Stream Processing Platform:** The stream processing platform aggregates and pre-processes the data coming from IoT sensors and normalizes it to a standard format which is understandable to SAP systems. This component becomes quite crucial as it filters and transforms data in such a way that only data of relevance actually reaches the SAP environment.
- **SAP HANA:** SAP HANA serves as the central processing hub where in-real-time data is stored, analyzed, and validated. It provides high-speed processing for both data and analytics. Using in-memory computing, SAP HANA makes sure that access to data is increasingly faster and performs an immediate validation of those according to anomaly rules as set in advance.
- **Data Validation Engine:** The engine, integrated into SAP HANA, applies validation rules to incoming data, such as identifying conditions like anomalies, inconsistencies, or missing values. As a matter of fact, the validation should happen instantly in order for integrity and quality data to feed into the business processes.
- **Analytics and Reporting Module:** This module presents real-time insights and visualizations along with alerts based on the data that is being processed and presented to help stakeholders comprehend data quality and operational performance. It thus furnishes actionable insights to the decision-makers so that they may take proactive measures toward such data quality issues before they start impacting business outcomes.
- **Security and Compliance Layer:** This is a layer that includes security to enable encryption, authentication, and access control of sensitive data across the architecture. Data security and compliance with regulations are most important ways to maintain trust and organizational assets.
- **Integration APIs:** Application Programming Interfaces are responsible for seamless integration among IoT devices, the stream processing platform, and SAP systems. Well-defined APIs will provide seamless data exchange and interoperability to let different components in the architecture commun icate properly.

B. Use Case Scenarios

The integration of IoT sensors with the SAP system for real-time monitoring in various practical applications opens various avenues across industries. Further, this section will present use case scenarios to effectively demonstrate the effectiveness of the proposed approach:

- **Manufacturing Quality Control:** IoT sensors are attached to the production equipment in a manufacturing plant for continuous monitoring of critical parameters concerning temperature, vibration, and pressure. The sensors will be collecting data continuously and sending data to the SAP HANA system for processing. Real-time data validation is performed in this system engine by anomaly checks. All notifications are sent immediately to operate on, thus helping them avoid defects on the production line well in advance to make good quality products and waste reduction.
- **Energy Management:** IoT sensors at an energy production facility monitor every parameter related to energy output, efficiency of equipment, and environmental conditions. Data is captured and sent to the SAP HANA platform for analytics in real time to detect inefficiency or operational anomaly detection. The system develops insights that allow operators to optimize energy production processes, reducing operational costs while improving overall efficiency without compromising on the quality of the data.
- **Healthcare Monitoring:** Wearable IoT sensors are installed in every patient's body to monitor all the real-time vitals: heart rate, blood pressure, oxygen level. It

transmits data to the SAP system for analysis. Real-time validation checks will be performed at the SAP system. In case any of those vital signs are out of the normal range, alerts would be sent to the medical staff. It involves proactive monitoring, whereby the care provider acts accordingly in a timely manner for improved patient outcome and ensures that health regulations are adhered to.

- **Environmental Monitoring:** IoT sensors in agriculture help monitor soil moisture, temperature, and nutrient levels. The gathered data would later be integrated into the SAP system, which would apply real-time quality checks and analytics to find the most opportune conditions for growing crops. Lastly, farmers would analyze that information to make strategic decisions over yield and resource efficiency to help them settle on better agricultural methods.

V. Conclusion

The integration of IoT-based monitoring of data quality into SAP Systems opens new horizons toward higher data integrity and operational efficiency. At the same time, real-time streams of data from IoT sensors allow for the immediate detection of anomalies, verification of accuracy, and assurance of data integrity within SAP environments. This proactive approach to data quality not only prevents potential issues before they impact business outcomes but also equips organizations for informed decisions with precision provided by accurate insights. The use of IoT connected with SAP systems finally develops a culture of responsiveness and continuous improvement, placing businesses in a strategic performance and competitive advantage in an increasingly data-driven world.

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Simplifying Complex Business Rules with SAP BRFplus: Real-World Use Cases

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***Abstract*— Business rules are a critical foundation for running any company, and while they can be defined in many ways, one thing is clear: they're always changing. In modern ERP systems like SAP, it's essential for business decision-makers to easily access and update these rules. To support this, SAP includes a built-in Business Rules Management System (BRMS) that helps ensure business processes are well-governed, even when custom enhancements are added. In this article, I'll share two real-world examples that demonstrate how these tools can simplify and maintain business rules effectively.**

Keywords—SAP, SAP ERP, BRF+, BRFPlus, Business rule framework, Business rules

I. Introduction

Rules play a fundamental role in our daily lives. They can be broadly defined as guidelines that indicate what should be done or what is expected in a given situation, such as: "Email attachments must not exceed 50 megabytes", "You must stop the car at the STOP sign,". In the business context, rules may arise from legal requirements, organizational policies, processes, expert knowledge, and more. Often, these rules are documented on paper, stored in spreadsheets, or even only exist in people's minds, making their integration into business software challenging. Traditionally, this has required either expensive custom development or complex processes to support manual decision-making.

A Business Rule Management System (BRMS) streamlines this by enabling rules to be implemented, accessed, and managed centrally. This approach separates rule logic from general application logic, allowing rules to be modified independently as requirements change. At SAP, various tools are available for defining specific types of rules for particular use cases. BRFplus is a newer BRMS that can consolidate these tools into a single solution. Its initial functional release was included in the 2008 Enhancement Package 1 of SAP NetWeaver 7.0. Initially, due to several limitations, it was used internally at SAP or by select customers. However, the first unrestricted version became available with Enhancement Package 2 of SAP NetWeaver 7.0. Despite its potential and growing interest, BRFplus is still not widely recognized among customers due to limited availability of information and resources.

The Business Rules Group, an independent organization focused on establishing standards and definitions related to business rules, defines a business rule as "a statement that defines or constrains some aspect of the business. It is intended to assert business structure or to control or influence the behavior of the business." [1] Business rules outline the operations, definitions, and limitations that apply to an organization, and they can govern people, processes, corporate behaviors, and computing systems, ultimately helping the organization achieve its goals.

Barbara von Halle offers a similar perspective, describing business rules as a "formal expression of knowledge or preference, a guidance system for steering behavior (a transaction) in a desired direction. On a larger scale, business rules serve as a guidance system that influences the collective behavior of an organization's people and information systems." [2]

These definitions are broad, encompassing various types of rules. For example, the rule "Smoking is prohibited inside all company buildings" fits these definitions. However, not all business rules are directly related to business operations. To manage them effectively, it is necessary to narrow down the scope to rules that are relevant to business operations. This leads to another common constraint used when defining business rules: a business rule should specify constraints on the creation, updating, and deletion of persistent data in an information system.

II. Business Rule management systems

A Business Rule Management System (BRMS) is a software platform that helps organizations define, deploy, monitor, and maintain complex decision logic that drives their operations. This decision logic, referred to as business rules, defines the behaviors and actions an organization must follow based on specific conditions. BRMS allows businesses to separate these rules from core application code, making them easier to manage and update independently from the software that implements them. This flexibility is key in today's dynamic business environment, where regulations, market conditions, and internal policies are constantly changing.

One of the primary advantages of using a BRMS is the ability to reduce the reliance on IT departments for changes to business logic. Since business analysts or domain experts can define and modify rules without needing extensive programming skills, it speeds up the decision-making process and makes organizations more agile. A BRMS typically provides an intuitive interface, often graphical, where rules can be configured, tested, and deployed with minimal risk to ongoing operations.

Additionally, BRMS ensures that rules are consistently applied across different systems, departments, and channels, maintaining a uniform approach to decision-making. This consistency is crucial for ensuring compliance with industry

standards and government regulations, especially in highly regulated sectors like finance, healthcare, and insurance.

Moreover, as businesses grow and scale, BRMS allows for easier modification of rules without disrupting existing operations. BRMS platforms also support rule versioning and auditability, which are vital for tracking how decisions are made and how they evolve over time. This ensures transparency and helps businesses avoid potential legal issues by providing a clear record of decisions made based on certain criteria. In short, BRMS empowers organizations to manage their decision logic efficiently, improve their response times to market changes, and maintain compliance with regulatory requirements.

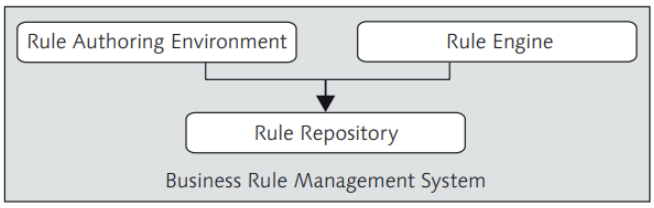

Fig. 1. Components of a Business Rule Management System [4]

BRMS systems usually require three components:

- An authoring environment for maintaining the rules
- A repository for storing business rules independently from the application code.
- A rules engine that executes business rules when triggered by the application code.

III. Business Rules in SAP ERP

SAP software has always provided customers with the flexibility to implement business processes. For simpler scenarios, configuration tables were utilized, while more complex configurations were handled through code exits such as Business Add-Ins (BAdIs). [5] Between these two extremes, numerous tools, engines, and frameworks have been developed over the past 20 years. Although many of them do not specifically identify as Business Rules Management Systems (BRMS), they offer functionalities that are somewhat similar. Some of these tools and frameworks were designed with a specific application in mind, while others were created to be reusable across various applications and processes.

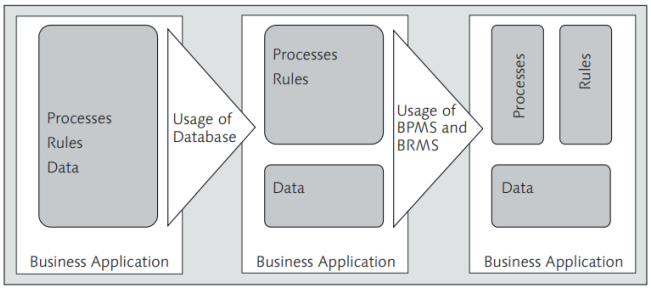

Fig. 2. Evolution of Business Application Architecture [4]

One of the most common solutions, in which SAP itself handles many business rules, is the so-called "condition technique". The condition technique is a powerful framework used to determine pricing, taxes, discounts, and surcharges in various business transactions, particularly in the Sales and Distribution (SD) and Materials Management (MM) modules. It enables businesses to apply different conditions based on defined rules or scenarios.

The condition technique involves the following key components:

- Condition Types: Define specific conditions like prices, discounts, or surcharges.
- Access Sequences: A search strategy SAP uses to find valid condition records from different sources
- Condition Tables: Store the actual condition records, such as prices or discounts, based on specific criteria (e.g., customer, material).
- Condition Records: Represent actual data that meets the conditions set in the condition tables.
- Pricing Procedure: A sequence of steps the system follows to calculate the final price, including all condition types.

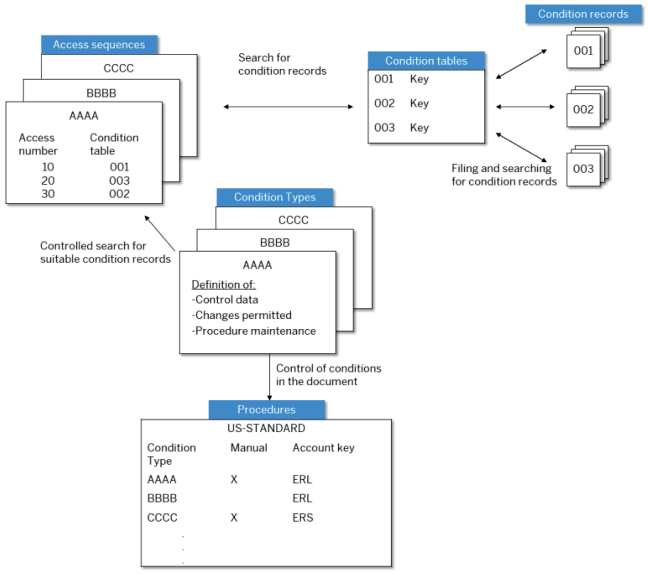

Fig. 3. How Condition Technique Elements Work together [3]

This technique is highly customizable, allowing users to configure complex pricing strategies, automate calculations, and ensure accuracy in transactions.

Another common solution, which is mainly used by companies for custom developments, is the creation of parameter tables. The creation of custom database tables and the relative ease of attaching maintenance views to them is an obvious solution as a quick and efficient way to store and maintain these parameters. The maintenance view has become a fashionable solution, and it definitely has the advantage of being able to store custom parameters with relatively little effort, but it has some drawbacks to consider: it requires development effort to extend and modify, and it lacks, for example, bulk data upload and download capabilities.

IV. SAP BRFplus

A. Authoring related features

BRFplus offers its user interface, the BRFplus Workbench, built using Web Dynpro ABAP technology. Since the Workbench runs entirely within a browser, no client-side installation is required. It can be used either as a standalone application or embedded into other application interfaces.

The Workbench supports data dictionary artifacts (DDIC), providing data element descriptions, documentation, and dynamic value help based on domain value lists and database entries. An extensibility feature allows users to create custom action and expression editors. It also offers configurable settings to tailor the Workbench to specific user groups or individual preferences.

Catalogs are available to organize rule artifacts in a flexible manner. Each building block of business logic has its own user-friendly interface. A comprehensive public maintenance API enables the development of custom UIs, while the simulation tool allows business users to test rules before deployment. Additionally, tools for tracking changes, performing consistency checks, conducting dependency analyses, and exchanging data through XML or Microsoft Excel are also available.

B. Rules engine related features

The BRFplus Rules Engine (BRE) offers an ABAP objects API that enables rules to be invoked and processed with minimal ABAP code. [6] It provides multiple methods for invoking rules, allowing flexibility in terms of performance and user experience. For remote invocation, generated web services and RFC-enabled function modules can be utilized. BRFplus also features a code generation framework designed for optimal performance and minimal processing footprint, with the option to extend it using custom action and expression types. This framework can dynamically generate or remove ABAP classes on demand without requiring user intervention. Additionally, BRFplus supports a special code version for runtime tracing, which allows for the verification and explanation of processed rules. The platform also incorporates "time-traveling" functionality, enabling rules to be processed based on their definitions at a specific point in time.

C. Rules Repository related features

The BRFplus rules repository is designed to accommodate various usage and deployment scenarios. It allows rule artifacts to be stored as either client-dependent or client-independent data, such as system, customizing, or master/application data. It supports both local and transportable content, with the latter linked to SAP's Change and Transport System (CTS) for automatic change recording. The repository enables data exchange via XML import and export, and artifacts can be versioned for change tracking and time-dependent rule processing. Permissions are managed using SAP's standard authorization framework, and access levels can be set to control the visibility and reuse of business rules. The repository also features a sophisticated lifecycle management system, supporting granular control over objects, which can be set as inactive, active, obsolete, or marked for deletion. Automatic dependency analysis ensures consistency across rule artifacts, while a search infrastructure allows users to query objects based on nearly any available attribute.

V. Real-word use cases and discussion

A. Comissing fee calculation

In the case of the company in question, different salespeople are assigned to each geographic location and receive a commission for sales in that area, according to the conditions set. As this commission distribution system has evolved over time, rather than all at once, each salesperson may receive a different commission from his newer colleagues according to different rules and principles. For example, some salespeople calculate their commission on the basis of a percentage, while others calculate their commission on the basis of the volume sold.

During the ERP implementation project, these were the first pieces of information we heard about this functionality. However, as the project progressed, more and more information about the current functionality was revealed, adding further complexity to the requirements.

For example, it has been found that for some sellers, a distinction has to be made as to which group of material they are selling, because the commission percentage is higher for one group than for another. In addition, even within a group, they may receive a higher commission for selling a particular item number. It was also found that for some sales colleagues the date of the calculation is based on the date of delivery of the goods, while for others it is based on the date when the buyer paid for the goods. This was important because salespeople renegotiated their commission contracts from year to year, so it was necessary to know the date on which to calculate the amounts in order to calculate accurately.

At this point, it became clear that the business process for calculating commissions was rather ad-hoc and that the number of vendors meant that there were as many commission contracts in place as there were vendors.
By the end of the business process survey, however, it was clear that the following dimensions affect the calculation of commission:

- Date of the goods delivered
- Date of the invoice paid by the customer
- Customer
- Country of the customer
- Material group of the material sold
- Material number of the material sold
- Sales channel the sales was made (webshop, direct order etc.)

Before going into the implementation process, it is worth noting that at the last minute it was even discovered that sometimes the CEO will make a separate agreement with the

salespeople on a specific sales order, that the salesperson will receive more or less commission on that order.

During implementation, several ideas were put forward to meet the specific need. These were, in order of time of emergence, as follows:

- Without automation, only queries are provided, the calculation itself is done outside the system
- Automation using standard tools within SAP
- Using the condition technique, where we write customized built-in logic behind each condition
- Develop a parameter table where the business can record the conditions and create a custom program
- BRF+ technology is used to record the conditions, which is used by a custom query to determine how much commission each salesperson receives in that month

It won't come as a big surprise, but the architect team decided that the last solution met the customer's needs. It's worth looking at the collective thinking that went into this decision:

- An automated solution is needed, where the calculation is not done by the staff
- The solution supports the possibility to calculate commissions based on "anything", not just on a predefined set of values
- The amount of commissions and the logic for the calculation should be modifiable by the client
- No technical or developer knowledge is required to modify the commission
- Be able to audit trail how the calculation rules have changed

Of the previously listed solutions, only the last two were able to address all the needs listed above. A fully customized solution was ultimately rejected for two reasons: it would have been difficult to extend with "anything" and the functionality required for auditability would have been too costly to develop. However, the BRF+ solution seems to have met all the expected requirements quite easily.

The following solution was therefore developed to meet the business need:

- A report collects all deliveries and invoices for a given period, at batch level
- For each of these lines, we perform the calculation given by the BRF+ application and see if a commission should be paid for that line, and if so, how much and to whom
- The result is sorted by vendor into a report, where subtotals are applied to the amount of the vendors

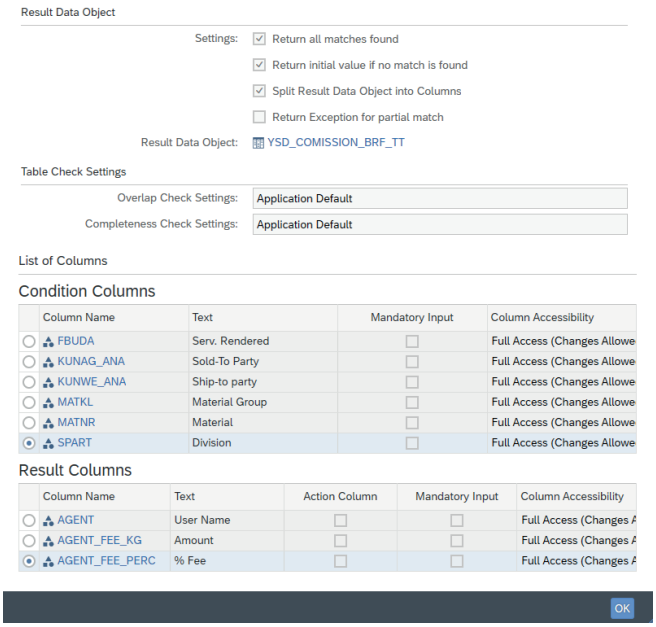

Fig. 4. Decision setting for comission calculation

Two specific things needed attention during development:

The first is that the basic functionality of the decision tables is that they stop at the first valid hit and return that hit as the result. In the case of the commission calculation, however, all valid hits have to be found, as there may be several salespeople associated with a single row. For this reason the decision table had to be set to "Return all matches found".

The second is that, although we tried to define all the parameters that are currently in use and could influence the calculation during the business need assessment, we had to prepare the solution to make all the business relevant data available for future extensibility. For this reason, all the data of the invoice voucher as well as the characteristics of the cycle are transferred during the calculation. This will ensure that these fields can be included in the calculation should the need arise in the future.

B. Assignment of batch numbers in food manufacturing industry

In the food industry and other highly regulated industries, there is an expectation that the life cycle of products should be traceable. This is due to the regulatory environment, see for example the pharmaceutical industry, as factories have to meet very strict traceability requirements to effectively implement product recalls in case of quality problems. But it is also because of such requirements that there is full life-cycle traceability of products in the automotive industry, and in the food industry in general.

In practice, this means that in the event of a quality defect in a finished product, it is possible to trace back precisely along the entire supply chain what components have been incorporated into the product, who has processed them and how. For example, in the case of a pizza made from pies, the manufacturer must ensure that the ingredients (flour, salami,

cheese, etc.) used in the pizza are from whom, when they were produced and what their nutritional value is. These suppliers must also meet similar standards, so that even the milk used to make the cheese that goes into the pizza can be traced back to the farm and the day it was produced.

Another example shows the logical steps to trace back the mud. Consider a finished food product on which an identifier has been placed in the form of a 2D barcode.

- The data content of the barcode is the product lot number this allows us to see which customers received the product and when
- The characteristics assigned to the lot (QM measurement results, production order number, expiry date, etc.)
- The production order number, which machines were used for the production, which shift the production took place on and who was operating the machine at the time
- The material movement documents show which raw materials were purchased (issued) for the production order
- The batch number of the raw materials makes it possible to trace which purchase order was used to receive them, when they were received, for how long and in which storage location
- The quality certificate and the measurement sheet supplied by the supplier can be retrieved from the document manager on the basis of the purchase order numbers

Within SAP ERP, most of the business needs for batch tracking can be met in a standard way. However, batch counting is an area where companies often have specific requirements. It is usually sufficient that these numbers are simply incremented one by one and allocated by the system. There are, however, cases where some form of "mask" must be used to help.

The business needs assessment has identified the following masks that the system needs to address:

TABLE I. BATCH MASKES

Requires Batch numbering	***Meaning***
YYNNN	Year & Julian day
YYMMDD	Year, Month, Day
YYMMDD	Year, Month, Day & Manual
YYNNNSSS	Year, Julian day & Silo No
YYNNN##	Year, Julian day & Incremental
YYNNNXXX	Year, Julian day & Manual

Material Group	Batch number mask
	YYNNNSSS## (Year, Julian day & Silo No & Increm...
=262004 (SF processed milk)	YYNNN## (Year, Julian day & Incremental)
=263001 (By-products)	YYNNNSSS (Year, Julian day & Silo No)
=261007 (Finished pr. milk)	YYNNN (Year & Julian day)
=261008 (Finished pr. sk.milk)	YYNNN (Year & Julian day)
=261009 (Finished pr. cream)	YYNNN (Year & Julian day)
=261010 (Finished pr.wheyconc)	YYNNN## (Year, Julian day & Incremental)
=262002 (SF standardized milk)	YYNNNSSS## (Year, Julian day & Silo No & Increm...
=262003 (SF titrated milk)	YYNNN## (Year, Julian day & Incremental)
=262012 (SF skimmed milk conc)	YYNNNSSS## (Year, Julian day & Silo No & Increm...
=261014 (Finishedpr skmilkcon)	YYNNN## (Year, Julian day & Incremental)
	YYNNN (Year & Julian day)
	YYNNN (Year & Julian day)

Fig. 5. Batch number mask determination based on material group

In selecting the technology for the right solution, it had to be taken into account that there was an explicit customer need to create additional batch masks and to expand the existing ones.

The BRF+-based solution met several critical needs in this respect:

- Due to the regulated industry requirements, it is audited who, how and when the decision tables have been modified, so that an audit does not cause disruption to individual development
- BRF+ formulas and logic can be modified by the client, no specific development knowledge is required
- Time-dependent functions are handled in a standard way in the technology, so it is easy to define specific date requirements

During the development, the standard SAP EXIT was used, in which the program calls the BRF+ application, in which the specific batch number is defined.

Within the application, two main things happen: a decision table is used to define the batch mask to be used, and in the next step the logic associated with the mask is executed, which breaks down the elements of the mask into parts.

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Cognitive Features in SAP Business Process Management

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***Abstract*—The article investigates the availability and effectiveness of modern solutions that support enterprises in addressing challenges related to Enterprise Architecture (EA) and Enterprise Engineering (EE). The research further explores whether these solutions provide substantial assistance to professionals and leaders in overcoming typical organizational challenges. By examining various Artificial intelligence and Cognitive technologies, including SAP LeanIX, SAP Signavio, and WalkMe, we assess their impact on simplifying processes and aligning organizational strategies with long-term goals, ensuring the efficient management of enterprise architectures.**

***Index Terms*— Enterprise Architecture, Enterprise Engineering, Artificial Intelligence, Business Intelligence, SAP Solutions, Digital Transformation, Cognitive Technologies, LeanIX, Signavio, WalkMe, Business Process Management.**

I. Introduction

In the rapidly evolving landscape of modern businesses, enterprises are increasingly required to operate as integrated systems that are agile, adaptive, and aligned with their strategic goals. Traditional organizational sciences have frequently failed to give businesses the resources they need to effectively handle this complexity. As a result, the field of Enterprise Engineering (EE), which focuses on the intentional design and optimization of enterprises, has emerged. Enterprise Architecture (EA) is the key concept of Enterprise Engineering. It is a framework that guides the alignment of an enterprise's processes, technologies, and organizational structures into an integrated whole. Studies have indicated that a considerable proportion of strategic projects fall short of the goals they set out to accomplish. Estimates suggest that between 70% and 90% of these initiatives, whether in the realms of total quality management, business process reengineering, or customer relationship management, fall short of success [1]. The main reason for these failures is frequently a lack of integration and coherence between the different parts of an organization, which leads to disconnected systems, misaligned processes, and organizational fragmentation. Businesses today operate within networks of collaborating entities due to the acceleration of globalization and technological advancements, allowing for an even greater level of integration. This complex environment demands a shift in the way enterprises are designed and managed. Traditional approaches, based on black-box knowledge (focusing on enterprise behavior without understanding the underlying structure), are insufficient. Instead, a white-box approach is needed, where the construction and operation of an enterprise are made explicit and systematically aligned with strategic goals [1]. This new paradigm is provided by EE, which sees businesses as intentionally designed systems that can be optimized. The idea behind EE is that an enterprise is a system that can be purposefully designed, re-engineered, and implemented to achieve particular objectives, rather than an organically growing entity. The EE approach draws heavily from systems theory, emphasizing the need to treat enterprises as complex systems where the relationships between processes, people, and technologies must be harmonized to achieve unity and integration [1]. In this scenario, the design of an enterprise must be coherent, ensuring that its various components work together in a unified way.

II. Enterprise Engineering and Enterprise Architecture

EA is a key tool within the framework of EE, that provides normative guidance for the design of an enterprise. EA is defined as a "coherent and consistent set of principles that guide how the enterprise must be designed" [1]. Its role is to ensure that the enterprise operates as an integrated whole, particularly in the face of complex and dynamic environments. EA is essential because it bridges the gap between high-level strategic goals and the operational aspects of an enterprise. Without a well-defined architecture, enterprises risk becoming fragmented, with misaligned processes and systems that do not support the overall strategy.

A. Enterprise Architecture Frameworks

Various Enterprise Architecture frameworks have been developed to support the design and management of enterprises in a structured and consistent way. These frameworks provide guidance for managing the complexity of enterprise systems by organizing their elements, interactions, and dependencies. Among the most commonly used frameworks are the Zachman Framework, TOGAF (The Open Group Architecture Framework), and ArchiMate [2].

1) Zachman Framework: Developed by John Zachman in 1987, the Zachman Framework is one of the earliest and most recognized enterprise architecture frameworks. It offers a structured approach to organizing and classifying the various perspectives of enterprise systems. The framework consists of rows (perspectives) and columns (dimensions) that together

form a matrix to represent different views of the enterprise—from the planner's scope to the owner's perspective, to the builder's configuration [3]. Each perspective is described by six fundamental questions: What? How? Where? Who? When? Why? This approach ensures that every aspect of the enterprise is considered and properly designed.

2) TOGAF (The Open Group Architecture Framework): TOGAF is one of the most widely adopted enterprise architecture frameworks globally. It defines four major architectural domains: business, data, application, and technology architecture. TOGAF's Architecture Development Method (ADM) provides a step-by-step approach to designing, developing, and implementing enterprise architectures, ensuring a comprehensive and aligned approach to managing the organization's structure and operations [4].

3) ArchiMate: ArchiMate is an open and independent EA standard, widely used in conjunction with TOGAF. ArchiMate defines three core layers: the Business Layer, Application Layer, and Technology Layer. These layers provide a formal way to visualize enterprise architectures and how different components interact. ArchiMate is particularly useful for aligning business strategies with IT solutions and ensuring that changes in the enterprise architecture are systematically managed [5].

These frameworks ensure that the different elements and layers of an enterprise are well-defined, aligned with the organization's goals, and adaptable to change.

B. The Architecture of the Enterprise

Enterprise Architecture is composed of various layers, each of which addresses a different domain of the enterprise's structure and operations. These layers form the foundation for managing the complexity of modern enterprises. Below are the key architecture layers:

1) Strategy Architecture Layer: The Strategy Architecture Layer is concerned with aligning the enterprise's strategic goals with its architecture. This layer defines the organization's vision, mission, and long-term objectives, translating them into actionable steps that impact the architecture at all levels. The strategy architecture ensures that the enterprise's overall direction is well-defined and that all architectural decisions support the achievement of strategic objectives [2].

In this layer, Enterprise Architects work closely with business leaders to ensure that architectural plans align with market trends, regulatory requirements, and future challenges. It also helps in identifying opportunities for competitive advantage through innovation and operational improvements.

2) Business Architecture Layer: The Business Architecture Layer defines the business functions, processes, and organizational structure of the enterprise. It ensures that the business's operations are optimized to achieve strategic goals efficiently. This layer focuses on core business processes, services provided by the enterprise, and the interaction between internal departments and external stakeholders [2].

In the business architecture, processes are modeled to improve workflow efficiency and to better align resources with business objectives. This layer also includes the organizational structure, defining roles, responsibilities, and the relationships between different business units.

3) Information Architecture Layer: The Information Architecture Layer is responsible for managing the data and information assets of the enterprise. This layer ensures that data is properly organized, stored, and accessible to the necessary stakeholders. The Information Architecture defines how information flows across the organization and how it is used to support business processes and decision-making [2].

Key components of this layer include data governance, data quality management, and the structure of databases and data warehouses. This architecture ensures that the right data is available to the right people at the right time, which is crucial for efficient decision-making and operations.

4) Information Systems Architecture Layer: The Information Systems Architecture Layer deals with the applications and systems that support the business processes defined in the business architecture. This layer ensures that software systems are integrated and aligned with the organization's operations. Information systems are responsible for automating business processes, managing data, and facilitating communication within and outside the enterprise [2].

This layer focuses on application integration, ensuring that different systems communicate effectively, and on system scalability, ensuring that the enterprise's systems can grow in response to increasing demands.

5) Technology Architecture Layer: The Technology Architecture Layer is concerned with the physical infrastructure of the enterprise, including hardware, networks, and IT systems. This layer ensures that the technological foundation of the organization is robust, scalable, and capable of supporting the business and information systems architectures [2].

Key components of the technology architecture include servers, data storage systems, cloud infrastructure, and networking solutions. The architecture is designed to be secure, reliable, and efficient, ensuring that the enterprise has the technological capacity to meet current and future needs.

6) Service Architecture Layer: The Service Architecture Layer defines the services offered by the organization's IT systems. This layer focuses on the service-oriented architecture (SOA) approach, which allows for flexible and reusable software components that can be easily adapted to meet changing business needs [2].

Services in this architecture are treated as independent units that can be used across different business processes and applications. The service architecture is essential for improving the agility and scalability of the enterprise's systems, as it enables rapid deployment of new functionalities without disrupting existing operations.

The six layers of Enterprise Architecture provide a more granular and detailed view of an enterprise compared to the traditional four layers, enhancing clarity and allowing for better alignment between business strategy and operations.

C. Categorizing the Six Layers Based on Decision-Making Levels

Enterprise Architecture impacts an enterprise's decision-making processes at different levels: operational (short-term), tactical (medium-term), and strategic (long-term) [6]. These levels correspond to specific layers of EA, helping the organization make informed decisions across all timeframes.

1) Operational Level (Short-Term Decisions): Operational decisions are typically made by lower-level managers and operators, involving routine tasks and low-risk actions that must be executed efficiently within a short time frame (typically less than a year). In this category, the following layers support operational decision-making:

The Technology Architecture Layer focuses on the organization's hardware, networks, and infrastructure that support daily operations. Reliable and scalable IT infrastructure is critical for meeting immediate operational goals.

The Service Architecture Layer ensures IT services are flexible and responsive to short-term operational needs by providing reusable and adaptable services to efficiently handle routine processes.

2) Tactical Level (Medium-Term Decisions): Tactical decisions are typically made by mid-level managers and focus on resource optimization and medium-term planning (1 to 3 years). This level ensures alignment between operations and strategic objectives. The following EA layers are relevant at this level:

The Business Architecture Layer outlines the organization's business processes, functions, and roles, helping mid-level managers optimize these processes and ensure alignment with organizational goals.

The Information Systems Architecture Layer addresses the enterprise's applications and systems, helping mid-level management improve operational efficiency and plan for future growth by managing and integrating applications effectively.

3) Strategic Level (Long-Term Decisions): Strategic decisions are typically made by executives and top management, focusing on the long-term direction of the organization (over 5 years). These decisions shape the enterprise's future vision and goals. The following layers play a key role in supporting long-term decision-making:

The Strategy Architecture Layer aligns the enterprise's long-term strategic goals with its architecture, ensuring adaptability to future changes and guiding the organization's long-term vision.

The Information Architecture Layer ensures data governance, quality, and management processes are in place, providing reliable and actionable data for long-term strategic planning. Cognitive Information Systems (CIS) and techniques like Business Intelligence (BI) and Artificial Intelligence (AI) support strategic decisions by analyzing large datasets and offering predictions.

III. Enterprise Architecture and Enterprise Engineering challenges and SAP Solutions

Enterprise Architecture and Enterprise Engineering are essential for aligning an organization's processes and technologies. However, managing enterprise models like AS-WAS, AS-IS, and TO-BE presents challenges, including adapting to continuous changes, ensuring smooth transitions, and handling multiple initiatives simultaneously. This section explores these challenges and highlights how SAP's cognitive solutions, powered by AI and real-time analytics, help organizations streamline model management, improve decision-making, and ensure alignment with strategic goals.

A. Model related challenges and potential solutions

Enterprise models are complex and constantly evolving because they need to represent the organization at different points in time. These models are essential for planning, auditing, and executing transformation initiatives. The main types of enterprise models are [2]:

1) AS-WAS Models: This model represents the enterprise's past state, including former architectures and transformation plans that were considered or implemented [2].

The model is useful for auditing and accountability, providing justifications for past decisions. This might be a previous decision related to cloud computing technologies, considering the documentation related to the plans and reasons for this decision, such as the expectation to improve scalability and reduce costs. Even if the initiative was later halted or changed, the model preserves the original rationale.

2) AS-IS Models: AS-IS model always depict the current state of the enterprise, including ongoing operations and current transformation initiatives, which is essential for managing daily operations and responding to immediate events [2]. This might be the case when an organization is in the process of launching an e-commerce platform. This model includes current plans and models for website development, supply chain adjustments, marketing strategies, and staff training that are actively being pursued.

3) TO-BE Models: This model relates to the future expectation, outlines the desired future state of the enterprise, necessary for planning upcoming initiatives This is useful and necessary to estimate the duration, costs, and risks of future projects [2]. For example , when a company plans to automate its manufacturing process over the next period. The TO-BE model illustrate the future factory layout, required technologies like robotics and AI, projected changes in workforce roles, and anticipated improvements in production efficiency.

The model's related challenges were originates form the time difference, form the lack of integration and necessary holistic view and the related planning, than require specific effort to be able to handle form the organisation.
These challenges might be summarized in two key factors:

- **Dynamic Nature**: AS-IS and TO-BE models must account for multiple ongoing initiatives that may experience delays or changes, making accurate modeling difficult [2].

- **Transition Between Models**: TO-BE models become AS-IS as initiatives are implemented and eventually become AS-WAS. Keeping models updated requires continuous effort to reflect these changes [2].

The significance of the updated Model is based on two factors, that considers effective planning and alignment with the goals.

- **Effective Planning**: Accurate AS-IS and TO-BE models are crucial for successful transformation initiatives, affecting costs, timelines, and risk management [2].
- **Alignment with Goals**: Up-to-date models ensure that all parts of the enterprise are aligned with strategic objectives and can adapt to changes effectively [2].

B. Enterprise Architecture Challenges and SAP AI, Cognitive Solutions

1) Dynamic Nature of Models: Adapting models rapidly to align with continuous transformation initiatives is a continuous challenge. For example, continuous change in the regulatory environment requires a quick adaption of the environment and in case that relates to multinational environment increase the complexity and the challenges of the adaptability.

SAP PowerDesigner leverage their AI capability to predict the impacts of the potential changes across the enterprise landscape. With its cognitive capabilities SAP Power Designer enable customers to make corrective and proactive adjustments therefore ensure smarter decision-making in the enterprise. **SAP Signavio** focuses on business process discovery, value identification, and process governance. It ensures that business processes remain up to date as requirements change. Signavio's AI-driven insights help organizations identify value creation opportunities, automate governance, and ensure compliance with operational workflows. **SAP LeanIX** specializes in enterprise architecture (EA) and IT landscape management, defining EA strategies and aligning technology roadmaps. LeanIX supports dynamic updates to enterprise architecture models as organizations move from AS-IS to TO-BE states. It provides predictive analytics on the impact of IT changes, ensuring alignment with strategic goals. **SAP Cloud ALM** manages the SAP solutions landscape, helping enterprises continuously monitor and track application and process changes, ensuring the adaptability of models in real-time.

2) Transition Between Model States: Ensuring seamless transition from conceptual models to operational realities is a huge challenge in EA. This might be realized during moving from a prototype phase of a digital product to full-scale production and market launch, which means the increase of the TRL (Technical Readiness Level). As the starting TRL is lower and the required TRL is higher the challenge is definitely bigger or more complex for the enterprise. Specially if the gap is high between the starting and ending TRL.

To support enterprises, **SAP Solution Manager** incorporates advanced machine learning algorithms to forecast possible difficulties during transitions between different model states. With its cognitive capabilities, SAP Solution Manager optimizes resource allocation and ensures smoother transitions by providing real-time analytics, enabling proactive adjustments during project tracking and resource planning. SAP Solution Manager's robust Change Control Management, Test Suite, and Landscape Management tools further streamline the process by minimizing risks and ensuring project alignment with business goals. These functionalities are enhanced by integration with hybrid landscapes, including SAP S/4HANA, providing end-to-end visibility and control throughout the lifecycle of both SAP and non-SAP systems. **SAP S/4HANA** leverages in-memory computing through its HANA database, enabling real-time analytics and insights across various enterprise processes. This capability is crucial when managing transitions between enterprise models, such as from AS-IS to TO-BE states, as it allows for immediate reflection of changes in data. This real-time adaptability reduces the time lag between planning and operational implementation, which is key to ensuring that architecture dynamically adjusts as transformation initiatives unfold. **SAP LeanIX Predictive Analytics** and **SAP Predictive Engineering Insights** offer complementary predictive capabilities that assist in both architectural and project-level decision-making. SAP LeanIX Predictive Analytics: Assists decision-makers by offering predictive insights into how IT landscape changes will impact enterprise architecture. SAP Predictive Engineering Insights: Simulates engineering-specific scenarios, offering predictions related to resource allocation and project outcomes.

3) Continuous Model Updating: It is a strategical challenges, which originates from the continuous changes in time. To maintaining models in real-time, with ability to immediate reflects in the operational shifts is an essential requirement, however is a huge strategical decision and its might impact the enterprise heavily.

This might be caused, due to rapid and sometimes even unexpected shifts like for example due to unexpected global market change, which drives tot he supply chain strategy.

SAP Enterprise Architecture Designer (EAD) might be a solution as it integrates real-time data analytics and AI. This integration contains a dynamically update, meanwhile refines the models, ensuring they are always aligned with current business conditions. **SAP Leonardo** combines AI, IoT, machine learning, and blockchain technologies to drive digital innovation. This system enables businesses to adapt quickly to changes by leveraging cognitive tools, helping organizations update and evolve their models to keep pace with industry transformations. **SAP Asset Performance Management (APM)** complements these efforts by using AI-driven predictive analytics to monitor and optimize asset performance. APM ensures that real-time operational data is integrated into enterprise models, allowing businesses to forecast equipment failure, optimize maintenance schedules, and dynamically adjust operational models to prevent disruptions. Similarly, **SAP Digital Manufacturing** plays a crucial role in keeping manufacturing models updated in real time. AI-driven insights into production schedules, machine performance, and quality control help manufacturers adjust their operational models to reflect actual factory conditions.

4) Alignment with Project Management: Integration a project management with enterprise architecture for holistic oversight and enhanced planning. There is a need for coordinating technology upgrades across different business units to improve overall operational efficiency. Lack of this activity significantly degrade the smooth and effective operation of the enterprise, that might harm the enterprise overall interest.

SAP Portfolio and Project Management (PPM) with the use of AI-enhanced analytics provide deeper insights into project impacts. The tool optimizes decision-making and ensures that projects are aligned with strategic enterprise goals.

5) Managing Multiple Initiatives: Managing multiple initiatives simultaneously might cause overlap or conflicts.

At the same time implementing various systems, like new HR systems and customer relationship management solutions, might create an internal conflicts of interest that negatively impacts the entire organisation, might harm the enterprise internal end external interests.

SAP Transformation Navigation applies advanced cognitive technologies, integrated with SAP BTP, to analyze and prioritize multiple initiatives by evaluating their strategic impact. It provides insights into resource usage, potential ROI (return on investment), and strategic alignment, helping businesses make data-driven decisions. Through real-time analytics, prescriptive guidance, and strategic impact mapping, the tool ensures that decision-makers can prioritize initiatives effectively, avoiding resource conflicts and maximizing the value of concurrent projects across business units. **SAP Emarsys** complements these efforts by leveraging AI to manage and optimize marketing initiatives. It delivers personalized marketing campaigns based on customer behavior, ensuring that marketing projects align with overall business goals and do not conflict with other ongoing initiatives.

C. Enterprise Engineering Challenges and SAP AI, Cognitive Solutions

1) Complex Project Execution: In any enterprise life executing complex projects with efficiency and precision is a common challenge. Upgrading enterprise-wide cybersecurity measures in response to emerging threats is an very often occurring example.

SAP Advanced Planning and Optimization (APO) integrates AI-driven capabilities to simulate various scenarios and predict outcomes. Its cognitive features, combined with **SAP Integrated Business Planning (IBP)** for more holistic insights, enable organizations to optimize project delivery by precisely allocating resources, mitigating risks, and anticipating potential challenges. **SAP Ariba** complements these efforts by applying AI-driven procurement optimization. By automating sourcing and contract management processes, SAP Ariba streamlines complex procurement tasks, ensuring timely and cost-effective sourcing of materials and services for large-scale projects. Ariba's AI capabilities enable predictive insights into supplier performance, helping organizations anticipate potential supply chain disruptions and mitigate risks.

2) Resource Allocation Efficiency: Optimally distributing resources across competing projects and demands. Inappropriate allocation IT and development resources between ongoing maintenance and innovative tech projects may cause loss of financial, that negatively impact the enterprise, meanwhile might cause serial problems within human resources on even single employee level.

SAP Human Capital Management (HCM) employs predictive analytics and machine learning to forecast resource needs. It optimizes staffing plans, ensuring the right talents are engaged at the right time. **SAP SuccessFactors** enhances this further by using AI to provide personalized recommendations for employee development, succession planning, and workforce scheduling, ensuring that the most critical projects are resourced efficiently without disrupting ongoing maintenance or innovation efforts. **SAP Fieldglass** optimizes the management of external workforce resources, leveraging AI to ensure the effective allocation of temporary staff and contingent labor. This solution helps enterprises assign the right resources to the right tasks, particularly for projects requiring external expertise, further improving resource allocation efficiency. **SAP Concur** optimizes the management of travel and expense resources by automating expense tracking and approval workflows. Its AI capabilities help organizations allocate resources efficiently, ensuring that employee expenses align with project budgets and corporate policies, thus preventing overspending and ensuring accountability. **SAP Customer Experience (CX) AI Solutions** use AI-driven tools enhance customer engagement by analyzing behavior patterns and providing personalized insights. They help businesses improve customer satisfaction by offering tailored experiences, optimizing engagement strategies, and driving customer loyalty. **AI-Driven Predictive Maintenance** is focused on operational stability by analyzing equipment and system performance. Using AI, it predicts when maintenance is required to prevent equipment failure, optimize resource allocation, and avoid system downtime. This ensures that critical infrastructure remains operational, improving overall system efficiency.

3) Coordination of EA and EE Efforts: Coordination of EA and EE Efforts means to aligning enterprise engineering projects with strategic enterprise architecture. It might be during integration of newly acquired technology assets after a merger or acquisition.

SAP Integration Suite uses advanced algorithms to integrate disparate systems, ensuring compatibility and facilitating seamless integration. It's recognized for enabling real-time SAP-to-non-SAP system integration, as well as offering capabilities that support AI-powered process automation and dynamic connectivity, enhancing overall enterprise synergy.

4) Adaptability to Strategic Changes: Adaptability to strategic changes is the activity that require to quickly modifying engineering processes to accommodate new business strategies and models. Swift adaptation to a shift towards more sustainable business practices.

SAP Business Technology Platform (BTP) facilitates the rapid development of adaptable applications that respond to

evolving business needs. **The AI Foundation** on SAP BTP supports this adaptability by offering a suite of tools SAP AI Services: Includes Document Information Extraction, Data Attribute Recommendation, Personalized Recommendation, and SAP Translation Hub, automating data handling and improving customer engagement and communication. AI Lifecycle Management: Through the Generative AI Hub, it automates process generation, helping businesses scale and streamline operations. Business Data & Context: Tools such as SAP HANA Cloud Vector Engine, Knowledge Graph Engine, SAP Datasphere, and SAP Knowledge Graph ensure advanced data processing, governance, and enhanced decision-making through connected data points.

D. Enterprise Architecture Management related Challenges

As Enterprise Architecture continues to evolve, organizations face numerous practical challenges that impact their ability to maintain alignment between business strategies and IT capabilities. These challenges go beyond model management and touch on the operational realities of implementing and sustaining EA frameworks. From documentation issues to communication gaps and governance complexities, enterprises struggle to keep pace with technological advancements and organizational changes.

A comprehensive study identified 44 distinct challenges faced by EA management, which can be categorized into six key areas: documentation, planning, implementation, communication, support, and governance [7]. These long-standing issues are further amplified by emerging trends such as the API economy, Software-as-a-Service (SaaS), and the rise of citizen developers leveraging low-code/no-code platforms [8]. As these trends reshape the technological landscape, organizations must adjust their EA practices accordingly to remain agile and competitive in an ever-evolving environment.

1) Documentation: Maintaining accurate EA documentation is time-consuming and prone to errors, largely due to manual processes [9]. As organizations grow and adopt new technologies, the complexity of EA landscapes increases, making it difficult to keep documentation current. Unclear responsibilities and knowledge gaps among stakeholders further contribute to outdated and incomplete documentation [10]. This lack of clarity leads to decision-makers facing cognitive overload, as they struggle to process incomplete or incorrect information. Additionally, over-detailed documentation can increase workload, while overly static models fail to adapt to changing business needs [11].AI solutions can significantly reduce these challenges by automating the documentation process and ensuring transparency.

WalkMe AI Documentation Tools: Employs AI to capture workflows automatically, generating documentation dynamically based on user interactions. This system leverages user behavior data to create accurate and contextual help documentation. **SAP LeanIX APM (Application Portfolio Management)**: Integrates AI to track changes in the application landscape, ensuring that documentation is always accurate and reflects the most current state of the application portfolio. **AI-Based Document Classification (SAP Signavio)**: Implements Natural Language Processing (NLP) to efficiently categorize and organize documentation. This AI functionality enhances the searchability and accessibility of documents by intelligently tagging and sorting them. **Process Model Auto-Completion**: Leverages AI to aid in the creation or updating of business process models by predicting next steps in a process based on recognized patterns. This tool simplifies model development and increases efficiency by automating part of the modeling process.

2) Planning: The planning phase of EA is focused on designing a future architecture that aligns with the organization's long-term goals. However, planning is frequently hindered by the interdependencies of various EA components, making the process complex and difficult to manage [12]. Changes in the business and technology landscapes, both expected and unexpected, further complicate the process. Unexpected changes, in particular, can be costly and may require significant replanning. Additionally, the planning process is often impacted by a lack of knowledge and involvement from key stakeholders, creating a barrier to effective planning [13]. Communication gaps between stakeholders during the planning phase exacerbate these issues, as conflicting priorities or limited time may result in plans that do not fully meet organizational needs.

SAP LeanIX Predictive Analytics: Provides strategic road mapping and forecasts how system changes will impact the overall architecture. By helping decision-makers foresee the effects of modifications, it ensures that architectural updates align with long-term business objectives, making it an essential part of planning for future growth. **SAP Signavio Collaboration Hub**: Facilitates real-time collaboration and scenario modeling, ensuring alignment between business and IT during the planning phase. **AI-Driven Planning (SAP Analytics Cloud)**: Simulates various planning scenarios and helps optimize resource allocation and long-term strategies. **Business Capability Mapping (SAP LeanIX)**: Uses AI to map out business capabilities and align them with the resources required for future projects. **SAP Enterprise Architecture Designer**: Provides advanced modeling capabilities, ensuring alignment with strategic goals. **SAP Analytics Cloud**: "Just Ask" feature leverages AI to enable scenario simulations and planning projections. It allows teams to test different architectural changes, ensuring their plans align with future business requirements.

3) Implementation: Implementation is where plans are put into action, translating architectural designs into working systems. However, this phase is often fraught with difficulties, including a lack of communication and support from stakeholders [14] and insufficient governance structures [15]. The use of outdated or unused documentation further complicates implementation efforts. Employees may resist changes to familiar systems and processes, leading to a lower willingness to adopt EA initiatives. Missing management commitment and unclear expectations within the organization also present major challenges [16]. Finally, the difficulty of transitioning to new

architectural frameworks that align with organizational norms and values further complicates implementation efforts. AI-powered tools can reduce friction during implementation by automating processes and improving support.

SAP Signavio Process Monitoring: Tracks the execution of processes and flags deviations to ensure systems are implemented as planned. **Tricentis Automation for Testing**: Uses AI to automate testing of new systems during implementation, ensuring a smoother transition. **AI-Driven Change Management**: Automatically identifies areas of resistance and suggests mitigation strategies to ensure smooth adoption of EA initiatives.

4) Communication: Effective communication is essential for aligning stakeholders with EA initiatives, but many organizations struggle to maintain consistent messaging across departments. A lack of communication during the architecting process can negatively impact the implementation and governance of EA projects. Additionally, communication gaps often arise from stakeholders using the same terminology in different ways, leading to misunderstandings. Limited support from management and insufficient resources for communication efforts further hinder the success of EA projects [17]. AI-powered solutions help bridge communication gaps by creating a shared platform and fostering collaboration.

SAP Signavio Collaboration Hub: Acts as a central platform for stakeholders from both business and IT to collaborate in real time. **AI-Based Language Translation**: Uses natural language processing (NLP) to translate technical jargon into business-friendly language, improving communication across departments. **SAP LeanIX Integration**: Provides visual representations of the IT landscape, helping stakeholders understand the impact of changes on different business units. **AI-Powered Data Insights (SAP Analytics Cloud)**: Automatically generates reports and insights in a format easily understandable for non-technical stakeholders. **WalkMe AI**: Enhances communication through automated guidance, ensuring that both technical and non-technical users understand the processes and systems.

5) Governance: Governance plays a crucial role in ensuring that EA initiatives are aligned with organizational standards and objectives. However, many organizations struggle with unclear responsibilities and a lack of a central EA unit, leading to difficulties in enforcing governance rules [17]. Compliance with governance principles is further complicated by the use of legacy systems and external contractors, which can be costly to maintain and difficult to integrate into the as-is architecture. Additionally, a lack of understanding of EA among key decision-makers can obstruct governance efforts and lead to fragmented architecture [18].AI tools help automate governance processes and ensure compliance across the architecture.

SAP Governance, Risk, and Compliance (GRC): Uses machine learning to monitor compliance and manage risk across the entire enterprise. This tool provides an all-encompassing approach to risk management, ensuring that governance and compliance rules are adhered to in all systems and processes. **SAP Signavio Process Governance**: Focuses on automating governance workflows, ensuring that business processes meet predefined rules before execution. It is particularly useful for process-level governance, where enforcing consistency and compliance in operational workflows is essential **LeanIX Governance Features**: Specializes in IT governance, monitoring the IT landscape for compliance breaches. This tool automatically generates compliance reports and ensures that IT systems align with governance requirements, reducing the risks of system-related governance violations. **SAP Customer Data Cloud**: Plays a key role in governance by managing customer consent and ensuring compliance with data privacy regulations such as GDPR. Its Consent Vault securely stores customer consents, enabling easy audits and adherence to regulatory requirements.It also analyzes customer behavior to deliver personalized customer experiences, improve conversion rates, and build trust through transparency and consent management. **AI-Driven Policy Enforcement**: Automatically applies governance rules across various layers of the enterprise architecture, ensuring compliance with internal and external standards. **SAP AI for Data Privacy**: SAP AI for Data Privacy helps automate compliance with data protection laws like GDPR, ensuring that enterprise architectures meet legal standards. These AI tools monitor, assess, and ensure the protection of sensitive data, reducing the risk of privacy breaches and supporting data governance. **SAP AI Ethics and Compliance Hub**: The SAP AI Ethics and Compliance Hub focuses on promoting ethical AI use and ensuring that AI-driven systems comply with regulatory standards. It offers tools for governance of data and AI, emphasizing responsible AI practices while helping organizations maintain compliance in cognitive-driven systems.

6) Support: Enterprise architecture requires ongoing support to remain aligned with evolving business needs. However, organizations often face difficulties in providing adequate resources and technical expertise to support EA efforts. The limited capacity of enterprise architects, along with a lack of technical know-how, leads to perceptions of insufficient support [19]. This can delay the resolution of architectural issues and prevent the organization from adapting quickly to changes. Additionally, management may not fully support EA initiatives, restricting the allocation of necessary resources and hindering the long-term success of the architecture [7]. AI solutions can provide continuous monitoring and support to maintain EA efficiency.

SAP Enable Now: This digital adoption platform provides real-time, in-app support and training, integrated across multiple SAP solutions like S/4HANA and SuccessFactors. It offers multilingual capabilities, enabling global organizations to maintain consistency in training and documentation. By integrating with SAP Signavio, it supports process transformation, training, and continuous user enablement. Furthermore, SAP Enable Now's AI-powered features, such as automated content creation and translation, improve efficiency in maintaining training material and help users seamlessly navigate software. **SAP Signavio Process Intelligence and SAP**

Signavio Process Insights: Continuously monitor business process performance and provide real-time insights through AI and process mining. They identify inefficiencies, suggest improvements, and monitor compliance with organizational goals. By highlighting potential bottlenecks and areas for refinement, they ensure continuous process optimization and help businesses improve operational efficiency. **SAP Intelligent Robotic Process Automation (IRPA)** Automates repetitive, rule-based tasks (e.g., service requests, data entry), improving operational efficiency by reducing manual intervention in day-to-day support processes. This enables IT teams to focus on more strategic activities and minimizes human error in routine operations **SAP LeanIX Enterprise Architecture Monitoring**: Uses AI to detect system vulnerabilities or inefficiencies, providing recommendations for proactive improvements. **SAP Conversational AI**: Automates real-time user interactions through AI-powered chatbots. This tool enhances the efficiency of enterprise architecture support by automating support ticket resolution (AI-Powered Support Ticketing), handling customer inquiries, providing internal support, and automating workflows. By reducing manual intervention, it improves communication, resolves issues faster, and boosts operational efficiency. **SAP Joule** provides AI-driven insights to enhance decision-making by analyzing enterprise data, helping predict outcomes, identify trends, and optimize strategies. It integrates with various SAP systems to amplify their functionality. In SAP LeanIX, Joule offers predictive insights into IT landscape changes, ensuring alignment with strategic goals. With SAP Signavio, Joule supports business process optimization and compliance by providing real-time insights. In SAP S/4HANA, it delivers real-time operational insights, while its integration with SAP Analytics Cloud boosts predictive capabilities for scenario simulation and resource optimization. Joule also assists SAP Ariba by analyzing supplier performance for smarter procurement decisions and supports SAP SuccessFactors with personalized workforce recommendations for talent and succession planning.

7) Emerging Trends and Their Impact: The evolution of enterprise architecture is not only shaped by internal organizational challenges but also by external technological trends. Emerging developments, such as the API economy, Software-as-a-Service (SaaS), and the rise of citizen developers leveraging low-code/no-code platforms, bring both new opportunities and new challenges. These trends complicate existing enterprise architecture management by introducing complexities around integration, scalability, governance, and security. However, SAP AI-powered solutions provide tools to address these emerging challenges by enhancing automation, improving governance, and supporting faster integration of new technologies.

The API Economy: The rise of APIs enables faster system development and integration but introduces complexity in documentation (Challenge 1) and implementation (Challenge 3). APIs require constant updates to ensure systems are properly documented and integrated seamlessly. Failing to manage API integrations effectively can lead to fragmented systems.

Software-as-a-Service (SaaS): SaaS applications offer scalability but complicate governance (Challenge 5) and communication (Challenge 4). Departments often deploy SaaS applications independently, creating shadow IT that undermines governance structures and leads to fragmented systems, making communication and documentation across departments more challenging.

Citizen Developers: Citizen developers using low-code/no-code platforms provide agility in application development but challenge governance (Challenge 5) and implementation (Challenge 3). These decentralized applications often operate outside traditional governance frameworks, leading to misalignment during implementation and creating gaps in documentation [8].

IV. Digital Transformation with SAP Products

Throughout the preceding sections, we explored the multifaceted challenges organizations face in managing enterprise architecture and enterprise engineering. These challenges—ranging from maintaining up-to-date models, managing resource allocation, to addressing documentation and governance issues—highlight the complexity of aligning IT capabilities with business objectives in dynamic environments. We have also examined how SAP's AI-powered solutions provide valuable support in addressing these challenges through automation, real-time analytics, and enhanced decision-making.

In response to these complexities, Digital Transformation (DT) has emerged as a critical enabler for organizations to modernize and streamline their operations. SAP plays a pivotal role in facilitating this transformation with solutions like SAP LeanIX, SAP Signavio, and WalkMe. These tools provide comprehensive support for integrating business processes, improving IT architecture, and enhancing user experience, allowing organizations to not only overcome their existing challenges but also to position themselves for future growth.

A. The Power of SAP LeanIX and SAP Signavio for Digital Transformation

SAP LeanIX and SAP Signavio provide a comprehensive approach to Digital Transformation by integrating IT infrastructure modernization with business process optimization. SAP LeanIX enables enterprises to gain clarity over their IT landscape, managing their application portfolios and aligning their architecture with strategic goals. At the same time, SAP Signavio focuses on improving business processes through its process mining and modeling capabilities. This integration ensures that technical architecture and business workflows evolve in harmony, which is crucial for a successful transformation [20].

By combining LeanIX's ability to assess and modernize IT components with Signavio's capability to analyze and streamline processes, organizations can ensure that their transformation initiatives are both efficient and aligned with long-term objectives. The collaborative platform offered by these tools allows for continuous communication between IT and

business teams, facilitating a smoother journey from strategy to execution [21]–[23].

B. WalkMe: Enhancing User Experience in Digital Transformation

While SAP LeanIX and SAP Signavio address the technical and operational aspects of transformation, WalkMe adds a vital layer of user experience enhancement. During any large-scale transformation, one of the most significant challenges is ensuring that employees and end-users can quickly adapt to new systems and workflows. WalkMe provides real-time guidance, helping users navigate changes without the need for extensive manual training. Its in-app guidance feature offers contextual support, reducing learning curves and improving user efficiency.

WalkMe also automates the training process, allowing personalized walkthroughs that tailor to individual user needs. This ensures that employees are supported throughout the transformation journey, minimizing resistance to change and increasing system adoption rates. By tracking user behavior and interactions, WalkMe offers insights into how processes are being used, highlighting areas where additional support may be needed. This focus on user experience is a critical component in ensuring the success of Digital Transformation projects [24].

C. The Combined Impact of SAP LeanIX, SAP Signavio, and WalkMe in Digital Transformation

Together, SAP LeanIX, SAP Signavio, and WalkMe form a powerful trio that addresses the full spectrum of challenges in Digital Transformation. SAP LeanIX ensures that IT architecture is modernized and aligned with the broader business strategy, while SAP Signavio optimizes processes for greater efficiency. WalkMe complements these efforts by focusing on the end-users, providing the guidance and training necessary to ensure smooth adoption of new systems.

This integrated approach not only aligns IT and business goals but also accelerates transformation by enhancing user engagement. Employees can quickly adapt to changes in processes and systems, reducing downtime and boosting operational efficiency. Furthermore, these tools provide continuous feedback, allowing organizations to make data-driven improvements to both systems and processes over time. The combination of architecture modernization, process optimization, and user support is key to ensuring that Digital Transformation efforts are sustainable and impactful in the long run.

V. Conclusion

The increasing complexity of enterprise environments presents considerable challenges for organizations, particularly in managing their Enterprise Architecture (EA) and Enterprise Engineering (EE) frameworks. These challenges encompass a wide range of issues, from maintaining updated models and ensuring resource efficiency, to addressing governance, documentation, and strategic alignment. As businesses scale and evolve, these problems become more pronounced, requiring robust and targeted solutions.

There are advanced tools and technologies that effectively support both management and technical professionals in overcoming these challenges. SAP-driven AI and Cognitive solutions, including LeanIX, Signavio, and WalkMe, are among the leading examples of technologies that offer highly specific and tailored approaches to tackling particular issues. Each of these solutions is designed to address unique aspects of enterprise complexity, ensuring that critical problems are resolved with precision and efficiency.

Through review of the literature and a systematic analysis of existing tools and applications, it is evident that these AI and Cognitive technologies are pivotal in shaping the future of enterprise management. Their ability to provide targeted, effective solutions to both everyday operational challenges and long-term strategic issues underlines their role as indispensable assets in an organization's toolkit. As enterprises continue to navigate an increasingly dynamic business landscape, these solutions will play a crucial role in ensuring their resilience, agility, and sustained success.

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Use Cases of Generative AI for Enhanced Intelligent Process Automation in SAP Systems

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***Abstract*—The integration of Generative AI into Intelligent Process Automation (IPA) within SAP systems presents a significant advancement in optimizing business operations. While traditional IPA automates repetitive tasks and reduces human error, incorporating Generative AI adds enhanced capabilities such as dynamic decision-making, contextual understanding, and predictive analytics. This paper outlines a framework that combines IPA with Generative AI to elevate automation in SAP environments, enabling systems to manage complex workflows, respond to evolving data, and make real-time, autonomous decisions. Through use cases across various initiatives, we demonstrate how this approach improves efficiency, reduces costs, and scales operations. Additionally, we address the technical challenges and ethical considerations associated with deploying these intelligent systems, offering insights into their transformative potential.**

***Index Terms*—Intelligent Process, Generative AI, Use Cases, Process Automation, SAP Systems**

I. Introduction

The 4th Industrial Revolution, driven by digitalization, automation, and smart devices, is rapidly transforming work, business, and society. Companies must integrate digital technologies to enhance customer service, optimize operations, and improve decision-making, ensuring competitiveness and value creation in a fast-evolving landscape [1]. In the current era of data-driven decision-making, companies are continuously looking for new methods to glean useful insights from the massive volumes of data they gather. This approach has historically required both human skill and sophisticated analytical technologies. In contrast, Generative Artificial Intelligence (GenAI) opened the door to a new era of data analysis that might completely transform how businesses extract value from their data [2]. These days, intelligent technologies enable businesses to thoroughly examine the data they already have, producing insightful analysis. Organizations may improve manual operations with automated and digital solutions by utilizing algorithms and automation.

In the past, artificial intelligence (AI) was thought to span a number of important application domains, such as automated theorem proving [3], automated programming [4], computer vision [5], robotics [6], natural language processing [7], and intelligent data retrieval [8]. Nowadays, GenAI makes it simple to access digital information throughout the whole organization by easily linking it to corporate networks, cloud computing, and SAP applications [9]. By integrating GenAI and large language models (LLMs) into business systems, customers can automate repetitive tasks and explore new digital technologies [10]. This may enhance employee happiness, expedite processes, provide better customer service, and more.

AI is effortlessly integrated inside SAP applications, cloud, and business networks, making digital information freely available throughout the whole organization [11]. SAP intelligent technologies and solutions include critical technologies that are independent of any particular operating system. The solution also provides an enterprise-ready, cloud-based generative AI platform that is easy to use and connects with SAP's business applications and machine learning (ML) capabilities [12]. Developers may use a safe and scalable environment to improve company processes and apps through intelligent solutions. These can help businesses improve productivity while lowering expenses.

The implementation of SAP intelligent system integration can take months or even years in many organizations, and the requirement for outside consultants to re-engineer processes can drive up expenses for SAP installations to several times the initial product cost. These limitations demonstrate the potential of generative AI to reduce implementation time and costs by automating process analysis, optimizing implementation, and offering customized solutions. This article explores Intelligent Process Automation (IPA) and how Generative AI (GenAI) enhances and integrates it into business workflows. It discusses technology stacks, use cases, and examples while highlighting the advantages and potential applications of combining advanced machine learning with domain expertise.

II. Literature Review

System Applications and Products (SAP) in data processing allow clients to modify their Enterprise Resource Plannings (ERPs) to suit their unique requirements by converting its proprietary software into an open development and integration platform [13], [14]. To improve company operations and customer satisfaction for corporate clients, Intelligent Process Automation (IPA) aims to increase efficiency by facilitating more touchless transactions and smooth procedures.

The launch of ChatGPT by OpenAI has reshaped perceptions of AI, especially Generative AI, disrupting industries globally, including SAP [15]. This transformation is altering how businesses operate, data analysis, make decisions, and optimize processes. Unlike traditional AI, which relies on predefined rules and patterns, Generative AI can generate new data and insights, as well as creative outputs, enabling more complex interactions. SAP systems could enhance chatbots and virtual assistants by integrating LLMs that allow users to communicate with SAP solutions in natural language [16]. This eliminates the need for specific instructions to do operations like controlling workflows [17], retrieving reports [18], and carrying out transactions [19].

In recent years, SAP has been making significant investments in AI, integrating generative AI capabilities into its solutions and the SAP Business Technology Platform (BTP) [20]. Apart from this, AI has already been integrated into numerous sections of the supply chain, and it is positioned to have a substantial influence at both the beginning and conclusion of the process. These investigations primarily focused on the use of AI and ML in supply chain management [21]. Moreover, AI components can be similarly integrated with SAP S/4HANA Cloud modules for sales, procurement, finance, and the digital supply chain, among other modules [22].

Recently, SAP CoPilot introduced a cutting-edge AI-powered virtual assistant designed to enhance efficiency and teamwork in SAP environments. This is a digital assistant that provides intelligent support across several SAP applications by interpreting and reacting to user inquiries in real time through the use of NLP and ML [23]. SAP's digital assistant can be augmented with generative AI, allowing customers to ask plain-language inquiries like 'What are the sales figures for last quarter?' and receive human-like replies that pull data straight from SAP systems [24]. Currently, SAP Leonardo enables enterprises to take advantage of state-of-the-art technologies like blockchain, AI, IoT, and ML [25]. It accelerates digital transformation across sectors by giving organizations the ability to get insights, automate procedures, and provide personalized consumer experiences through pre-built solutions and tools.

III. Research Methodology

This section details the process of exploring generative AI integration with SAP Build (formerly SAP's IPA), focusing on how it can enhance automation and procedures. Guided by a mixed-methods approach, the study addresses ethical considerations such as data protection and informed consent, while analyses concentrate on process discovery, design, optimization, and AI-driven decision-making.

The flowchart (shown in Fig. 1) illustrates a structured approach to integrating Generative AI into SAP Build processes. The process begins with identifying potential use cases within the existing SAP systems, followed by an evaluation of their suitability for AI integration. Based on this assessment, a decision is made to either enhance existing tools, develop new AI-driven solutions, or implement a hybrid approach.

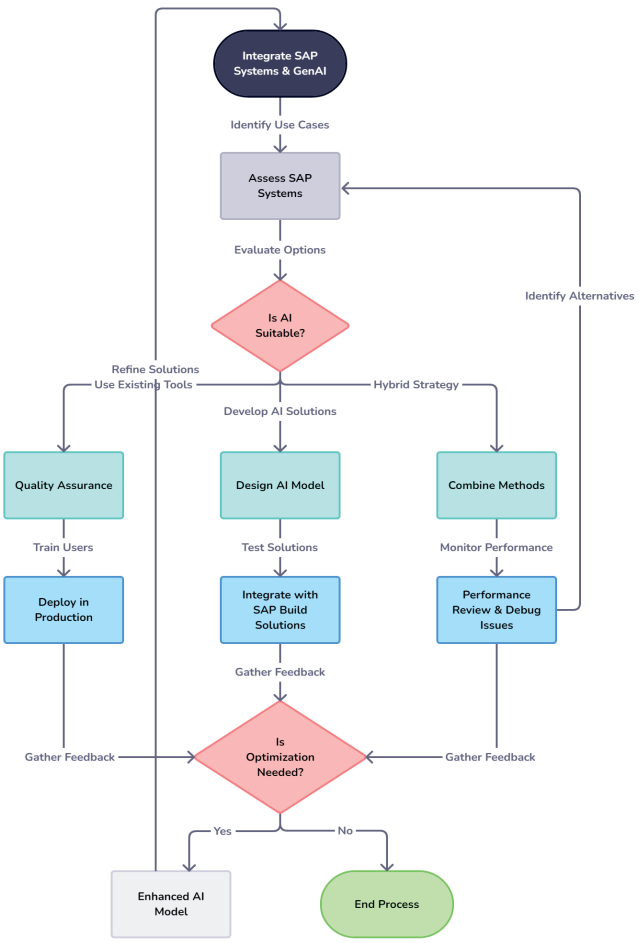

Fig. 1. SAP Systems and Generative AI Integration Flowchart

After deciding on an integration plan, attention turns to quality control, which includes user instruction, solution testing, and performance tracking. After a successful solution is linked with SAP Build, input is gathered to improve the procedure. To guarantee further optimization and enhancement of the AI-powered SAP Build procedures, a continuous feedback loop is set up.

There are a few key stages and decisions that need to be considered throughout the process.

1) Identify Use Cases: Determine which areas of SAP Build where generative AI may provide value, such as process discovery, design, optimization, or decision-making.
2) Assess SAP Systems: Determine if existing SAP systems are compatible with AI integration, taking into account variables such as data quality, infrastructure, and organizational preparedness.
3) Assess Options: Using the SAP system evaluation and the use case identification as a basis, choose the best integration approach.
4) Refine Solutions: If currently available tools are appro-

priate, improve them by adding AI features. If not, create fresh AI programs or use a combination of approaches.
5) Quality Assurance: To validate the standard and efficacy of the AI-powered solutions, do thorough testing and training.
6) Integration with SAP Build: To improve process automation, the AI solutions should be smoothly integrated with SAP Build.
7) Performance Review and Debugging: Keep an eye on performance at all times, spot problems, and make necessary adjustments to solutions.
8) Get Feedback: To guide continuous optimization and enhancement, get input from users and stakeholders.
9) Optimization: Assess whether more optimization of the AI-powered solutions is necessary based on feedback and performance analysis.
10) Final Steps: If more optimization is not required, the process ends with better SAP Build procedures and AI models.

This overall structure offers an organized method by which companies may use generative AI to improve their SAP Build procedures, resulting in more productivity, efficiency, and creativity.

A. Intelligent Automation Framework

The fundamental advantages of SAP are its deep domain and industry knowledge, its ability to access vast amounts of company data, and its comprehension of intricate business procedures.

While general-purpose large language models (LLMs) are pre-trained on vast datasets and offer significant potential, they have notable limitations. For instance, LLMs may rely on outdated training data and lack access to company-specific information or the context of specific business processes. Using proprietary datasets to refine LLMs and integrate them with real-time data pipelines might help overcome these challenges and guarantee more pertinent conclusions. Furthermore, integrating domain-specific information and ongoing model upgrades can improve their precision and consistency with business requirements. This approach aligns with the strategies outlined in Table II, emphasizing the importance of contextual and customized AI solutions in enhancing business processes.

Through the SAP Business Technology Platform (BTP) and a variety of major business applications, such as SAP S/4HANA, SuccessFactors, SAP Ariba, SAP Customer Experience (CX), and SAP Integrated Business Planning (IBP), SAP offers embedded AI capabilities. These artificial intelligence (AI) technologies increase the total value of SAP solutions by enabling users to easily take advantage of AI-driven automation and insights without the need for extra contracts or bespoke development. This makes integration easier and accelerates the adoption of AI across a range of business processes.

Alongside this, IT and business users may both simply set up and utilize the potential of AI inside the framework of their own business processes and data thanks to embedded AI. Across a variety of operations, this smooth integration promotes accuracy, efficiency, and more intelligent decision-making. One cloud-based solution that uses AI and machine learning to automate and streamline the order-to-cash process is SAP Cash Application. It greatly reduces human labor by automatically matching incoming money to open bills. Because the SAP Cash Application is integrated directly into SAP S/4HANA, companies may optimize their processes without requiring further custom programming or interfaces. This is but one example of how integrated AI benefits SAP's ecosystem with quantifiable economic value.

B. Use Cases of Generative AI and Intelligent Technologies

Intelligent technologies and generative AI are automating procedures and improving decision-making power, transforming company operations. These technologies provide efficiency and agility across a range of applications by being easily integrated into SAP S/4HANA and SAP Business Technology Platform (BTP) inside the SAP ecosystem. Table IV illustrates how these developments help firms increase overall productivity by streamlining workflows and drastically reducing manual labor. It also lists particular use cases and how they affect accuracy, agility, and efficiency.

C. Benefits and Technical Aspects of GenAI in SAP

The integration of Generative AI and Advanced Language Models (LLMs) into SAP systems' Intelligent Process Automation (IPA) marks a big step forward in how corporations simplify operations and improve decision-making. Businesses may utilize these cutting-edge technologies to automate monotonous operations, improve user interactions, and extract meaningful insights from large volumes of data. This section discusses the main technical consequences and benefits of integrating Generative AI into SAP settings.

- **Integration of Advanced Language Models:** Utilize APIs from Generative AI and Large Language Models (LLMs) to automate report generation, email drafting, and documentation processes within SAP workflows.
- **Natural Language Understanding (NLU):** Enhance user interactions through improved intent recognition and context understanding, facilitating accurate responses in conversational interfaces.
- **Contextual Awareness:** Enable SAP systems to maintain coherent dialogues over multiple interactions, enhancing customer service through personalized responses based on previous interactions.
- **Automation of Business Processes:** Automate complex tasks such as data entry and code generation, utilizing historical data to produce forecasts and actionable insights for improved decision-making.
- **Training on Domain-Specific Data:** Fine-tune LLMs with industry-specific data to enhance relevance and accuracy in outputs, ensuring alignment with organizational terminology and context.
- **Feedback Loop for Continuous Improvement:** Establish mechanisms to analyze user interactions, allowing

Components	Framework	Examples	Trends	Potential Direction
Embedded AI	Native integration within SAP solutions like S/4HANA and SuccessFactors.	SAP CoPilot, SAP AI Core, SAP Leonardo	Growing demand for seamless integration without extra contracts.	Higher user adoption with minimal setup.
Generative AI	Utilized in process optimization within SAP Build applications.	ChatGPT, DALL-E, SAP Business Technology Platform (BTP)	Increasing interest in generative capabilities for ERP.	Enhanced automation and predictive analytics.
Large Language Models	Effective in processing language but often lacks current context.	OpenAI's GPT-4, Google's BERT, Meta, Ollama, vLLM, Gemini	Shift towards tailored AI solutions for specific domains.	Development of real-time, context-aware applications.
Intelligent Process Automation	Merges machine learning with industry expertise for workflows.	SAP Intelligent Robotic Process Automation (RPA)	Rising trend in automating complex business processes.	Growth of hybrid models combining AI and RPA.
Use Cases of Generative AI	Applies to data extraction, content generation, and document processing.	Generative AI for Contract Review, Automated Report Generation	Increasing automation in customer service via chatbots.	Potential expansion into various business functions.
Predictive Analytics	Uses AI for advanced forecasting and analysis of trends.	SAP Predictive Analytics, Palantir, Tableau	Focus on data-driven decisions across industries.	Integration into critical functions like supply chain and finance.
Cognitive Automation	Systems are designed to learn and adapt through experience.	IBM Watson, SAP Conversational AI	The transition from basic automation to intelligent solutions.	Emphasis on self-optimizing and adaptive processes.
Future Automation Trends	Encompasses the integration of advanced AI technologies.	Hyperautomation, AI-Driven Process Mining	AI becoming central to automation strategies across sectors.	Focus on cognitive capabilities and predictive insights.

TABLE II
INTELLIGENT AUTOMATION FRAMEWORK AND COMPONENTS

Use Cases	Efficiency	Agility	Impact on Performance and Outcomes
Generative AI Applications	*AI Copilot, Automated Documentation* - Streamlines documentation processes, reducing report generation time.	Quickly adapts to user styles and preferences, facilitating tailored outputs.	Enhances productivity and consistency, accelerating project completion.
Conversational AI Systems	*SAP Conversational AI, SAP Joule CoPilot* - Automates customer interactions, enhancing response times.	Rapid deployment allows for quick iterations based on user feedback.	Increases customer satisfaction through efficient service delivery.
Robotic Process Automation (RPA)	*RPA Tools, SAP Build* - Automates repetitive tasks, significantly increasing throughput.	Easily scales to support new processes, improving adaptability.	Optimizes workflows and reduces operational costs.
Data Analytics and Forecasting	*Enhanced Analytics, Predictive Maintenance* - Provides timely insights into business performance.	Adjusts swiftly to new analytical requirements, promoting responsiveness.	Supports data-driven decision-making, enhancing forecasting accuracy.
Intelligent Process Optimization	*AI-Driven Optimization* - Streamlines workflows for improved resource allocation.	Facilitates agile responses to changing market conditions.	Maximizes operational performance through continuous improvement.
Testing and Development	*Test Case Generation, Code Analysis* - Speeds up software testing and increases coverage.	Integrates seamlessly into existing workflows for rapid iterations.	Improves software quality and reduces time to market.
Natural Language Generation (NLG)	*NLG for SAP Fiori, Automated Report Creation* - Automates report generation, ensuring user-friendly interactions.	Quickly adapts outputs based on user feedback for enhanced relevance.	Increases user engagement and satisfaction through accurate, contextual insights.

TABLE IV
USE CASES OF GENERATIVE AI AND THEIR IMPACT ON EFFICIENCY, AGILITY, AND PERFORMANCE OUTCOMES

iterative improvements to model performance and output relevance in SAP processes.
- **Ethical Considerations and Bias Mitigation:** Implement strategies for bias detection and mitigation to ensure equitable decision-making and uphold ethical standards in AI integrations.

Therefore, using APIs from Generative AI and Large Language Models (LLMs) to automate report production, email writing, and documentation operations in SAP workflows. This integration not only improves efficiency but also minimizes the manual labor necessary for these operations, enabling teams to focus on strategic projects.

D. Case Studies of Generative AI in SAP Systems

This section focuses on the practical uses of generative AI in SAP systems, showing how these tools improve productivity, decision-making, and client interaction. Examples of case studies that highlight the substantial advantages of integration include customer service improvements in a retail organization and procurement process improvements in a manufacturing company.

1) Real-World Case Study: Generative AI in Procurement [10]

   Let's look at a practical instance of generative AI-changing insights in SAP. SAP is used by a large manufacturing company to automate its purchasing procedures. Through the integration of generative AI into its SAP system, the organization experienced many significant improvements.
   a) **Demand Forecasting:** The system forecasts future demand for raw materials using previous data analysis, reducing remaining stocks and mitigating the risk of stockouts.
   b) **Anomaly Detection:** Anomalies in procurement transactions are found using generative AI algorithms, which help the business uncover fraudulent activity early and take measures to reduce expenses.
   c) **Automated Reporting:** To help stakeholders promptly incorporate essential details to make valid decisions, the system automatically creates procurement performance reports in natural language.
2) Generative AI in Action: A Case Study on Customer Service [26]

   Another example was the integration of generative AI into the SAP Customer Relationship Management (CRM) system of a large retail company. Following integration, the following improvements were made:
   a) **Enhanced Customer Interactions:** Through the application of natural language processing, the business enhanced the chatbot's comprehension of consumer queries, leading to quicker and more precise replies.
   b) **Personalized Recommendations:** To offer personalized recommended products and increase satisfaction with clients and sales, the system assessed user data and preferences.
   c) **Feedback Analysis:** Using generative AI techniques, the business was able to instantly uncover patterns and areas for development by analyzing consumer sentiment and input.

These case studies demonstrate how generative AI can improve decision-making, expedite procedures, and ultimately accelerate company success when it integrates into SAP systems.

E. Challenges, Limitations, and Future Trends

There are several types of difficulties and limitations when integrating Generative AI with SAP systems. Since SAP manages sensitive data, data security and privacy are critical. While it requires specialized knowledge, the complexity of integrating AI into existing workflows has the potential to affect operations. Ensuring model accuracy and dependability is crucial to retaining confidence, yet automated decision-making raises ethical considerations, notably about biases. Furthermore, evaluating large volumes of SAP data remains difficult, as traditional methodologies frequently struggle with its scale and complexity, resulting in delayed insights and failed chances for improvement.

SAP's future Intelligent Process Automation trends include technologies like as Hyperautomation, which combines AI and IoT to speed up operations with minimal human intervention. Moreover, Edge AI improves real-time automation by processing data locally, allowing for quicker replies. The SAP Business Technology Platform continues to incorporate powerful AI to enhance operations, while blockchain enables safe, transparent data and transaction automation.

IV. Conclusion

This study concludes that Generative AI in SAP Intelligent Process Automation has transformational potential. Artificial Intelligence (AI) and Large Language Models (LLMs) are automating processes, boosting decision-making, and increasing overall efficiency in SAP systems. Businesses may gain a competitive edge, simplify processes, and gather insights from massive volumes of SAP data by integrating Generative AI. Future studies can investigate deeper AI integration across a range of corporate activities, while also addressing ethical issues related to AI-driven automation. Companies that successfully navigate these challenges will be in a better position to fully use the potential of generative AI, opening the door to unprecedented levels of intelligence, creativity, and productivity. Integrating generative AI into SAP systems will be essential for promoting innovation and guaranteeing long-term success in a changing corporate environment as AI's influence grows.

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SAP lead time analysis in a company: a case study

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***Abstract*—The integration of lead-time optimization within SAP systems plays a crucial role in enhancing the efficiency of enterprise processes. This research aims to develop methods that enable accurate forecasting and comparison of actual and estimated lead-time values. Through optimization algorithms, planning accuracy for production and delivery processes can be improved by reducing discrepancies between actual and predicted lead-times. The results demonstrate that the application of appropriate forecasting techniques leads to significant cost savings and efficiency improvements in SAP-based enterprise resource planning systems.**

Keywords—lead-time, procurement, prediction

I. INTRODUCTION AND PROBLEM STATEMENT

Lead-time optimization is critical for enhancing efficiency and reducing costs in modern supply chains, particularly within SAP-driven enterprise resource planning (ERP) systems. The literature provides extensive insights into the impact of lead-time reduction on supply chain performance, inventory management, and operational efficiency.

Weiwei Fei et al. emphasize how lead-time uncertainty can lead to higher inventory costs and carbon emissions in supply chains. [1] Their study suggests strategies for mitigating these uncertainties through optimized order policies, thus improving sustainability. SAP systems also enable dynamic lead-time forecasting, which is crucial for predicting and managing supply chain delays. Mohammed Alnahhal et al. apply machine learning techniques to forecast lead times in make-to-order supply chains, improving shipment consolidation and reducing transportation costs. [2] Their work highlights the importance of advanced technologies in enhancing the accuracy of lead-time predictions. Hsu and Lee focus on optimizing replenishment and lead-time decisions in manufacturer-retailer chains, demonstrating how aligning these decisions leads to better service levels and lower costs. [3] Their findings are particularly relevant for users who seek to optimize inventory and replenishment strategies. Suri, in his work on Quick Response Manufacturing (QRM), emphasizes the importance of lead-time reduction across the entire production process. [4] QRM enhances competitiveness by reducing wait times in manufacturing systems. Lead-time optimization is also closely tied to inventory management. Gerchak and Parlar argue that reducing lead-time variability allows firms to lower safety stock levels, thereby reducing holding costs and improving inventory turnover. [5] This is critical for organizations using SAP to manage large inventories efficiently. Similarly, Kuhlang et al. propose a methodical approach to increasing productivity and reducing lead times in assembly and production-logistics processes, which is directly applicable to SAP's production planning modules. [6] The financial implications of lead-time optimization are explored by Tiedemann, who highlights the importance of identifying decoupling points in supply chains. [7] These points are critical for reducing lead times, improving return on investment (ROI), and ensuring that the benefits of lead-time reductions are maximized across the entire supply chain. Karki further demonstrates that managing customer order lead times has a direct impact on a firm's profitability, particularly in industries where customer satisfaction is tightly linked to on-time delivery. [8] Another key focus area is internal supply chain performance, where lead-time reduction fosters better coordination between departments. Ivanov and Jaff explore the positive impact of manufacturing lead-time reduction on internal supply chain processes, showing that faster response times improve overall operational fluidity. [9] Ray et al. similarly discuss the effectiveness of investments in lead-time reduction for make-to-stock products, stressing that such investments lead to greater production flexibility and reduced inventory costs. [10] In terms of strategic lead-time decisions, Ouyang et al. propose an integrated vendor-buyer inventory model that combines lead-time reduction with quality improvement. [11] Their study shows how optimizing both lead times and product quality can lead to significant cost savings, particularly when integrated with SAP's procurement and supplier management modules. Patterson et al. extend this by analyzing the adoption of new technologies for supply chain management, noting that technological innovations such as SAP play a key role in reducing lead times and improving supply chain integration. [12] Collaborative efforts in lead-time reduction are discussed by Simatupang and Sridharan, who emphasize the importance of supply chain collaboration in achieving shorter lead times and better overall performance. [13] Their findings support the use of SAP's collaborative supply chain tools to foster communication and coordination between partners. Narasimhan and Kim also highlight the strategic use of information systems in supply chain integration, showing how effective data sharing through SAP can lead to better lead-time management and cost savings. [14] You and Ignacio contribute to the literature by designing responsive supply chains that adapt to demand uncertainty. [15] Their research underscores the importance of flexible supply chain systems, which SAP can support through its advanced demand forecasting and inventory optimization features. Stalk similarly argues that time-based competition, where lead-time reduction is central, is reshaping global markets. [16] They suggest that companies using systems like SAP can gain a competitive advantage by minimizing lead times and improving responsiveness to customer demands. Spekman et al. investigate the role of partnerships in supply chain management, showing that closer collaboration between supply chain partners can lead to shorter lead times and more efficient operations. [17] Their findings suggest that SAP's collaborative tools are essential for firms seeking to improve lead-time performance through stronger partnerships.

SAP systems play a crucial role in lead-time management by streamlining data flow across departments, ensuring real-time visibility into inventory, production schedules, and supplier performance. This helps businesses anticipate delays and take corrective actions, improving overall efficiency [18]. SAP's features, such as supplier collaboration and inventory optimization tools, enable better lead-time forecasting and coordination with suppliers, which is key in reducing uncertainty in the supply chain [19]. Systems are particularly useful in industries with unpredictable demand and supply chain disruptions, allowing for more accurate production planning and timely deliveries [20]. Furthermore, SAP helps to mitigate the bullwhip effect in supply chains with stochastic lead times, reducing fluctuations in orders and inventory levels [21].

In this paper, we examine the lead-time from the procurement point of view. At a production company, the predicted lead-times come from the vendors, but the given lead-times are not always precise. Polynomial regression and neural networks were used to determine the acceptability of the given lead-time. Historical data are available from the company's SAP system. The company's name is secret, but the data are valid.

II. PROBLEM STATEMENT

At a manufacturing company, the estimated lead-times are provided by the suppliers, though these estimates are not always accurate. The inaccuracy can be originated from different possibilities:

- Human error: somebody typed in wrong data, either at the vendor or at our company.
- Faster delivery: the vendor provides the procured item sooner, e.g., vendor's production was quicker than they thought.
- Later delivery: the vendor provides the procured item later, e.g., vendor's production process was slower than they thought.
- Others: unpredictable situations.

To avoid wrong lead-time data, the company would like to classify the lead-time curves such as (1) believable, (2) dubious and (3) non-believable. If the judgement is (2) or (3) interaction between the company and its vendors are recommended.

The classification can be done at three levels at this company:

1. At product level. The lead-time is applied for one individual product.
2. At product category level. The lead-time is applied for a bunch of products, which has at least one common property (product family). In this case, the lead-time is calculated based on the average lead-time of the individual products assigned to the given product family.
3. At vendor level. Similarly to 2, the vendor lead-time is calculated based on the average lead-time of the products assigned to the specific vendor.

If new lead-time data are created at any level, the developed solution judges if the lead-time is believable or not. The judgement process is based on the prediction. Polynomial regression, more precisely, Cubic regression was used to predict the lead-times at all levels. The other method was the Long Short-Term Memory neural networks to learn the lead-times and make the predictions related to them.

The system is in test mode. For each product, product family and vendors, Polynomial regression and Long Short-Term neural networks should be calculated. In this paper, one product, one product family and on vendor are analyzed to demonstrate the whole process.

In the next section, the Polynomial regression and its prediction is introduced with the results. Then, Long Short-Term Memory neural network architecture is presented. Next, the results are presented while the last section conclude the paper.

III. POLYNOMIAL REGRESSION

Polynomial regression is an extension of linear regression that allows for modeling relationships between the dependent variable y and the independent variable x using higher-degree polynomials. Unlike linear regression, which fits a straight line to the data, polynomial regression can fit curves, making it useful for capturing non-linear patterns in data.

In a general polynomial regression model of degree n, the relationship between the dependent variable y and the independent variable x can be written as:

$$y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \cdots + \beta_n x^n + \varepsilon \qquad (1)$$

Where y is the dependent variable, x is the independent variable, β_0, β_1,…, β_n are the coefficients to be estimated, n is the degree of the polynomial and ε is the error term, capturing the difference between the observed and predicted values.

The choice of polynomial degree depends on the nature of the data. While a higher-degree polynomial can model more complex relationships, it also increases the risk of overfitting, where the model fits the noise in the data rather than the underlying trend. Cubic regression is a specific case of polynomial regression where the degree of the polynomial is $n = 3$, therefore the cubic regression equation takes the form:

$$y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \epsilon \qquad (2)$$

Cubic regression offers a balance by allowing for flexible curve fitting without the extreme flexibility of higher-degree polynomials, which can become too sensitive to small fluctuations in the data.

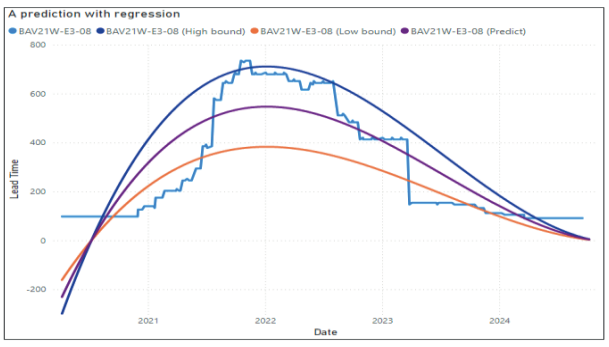

Figure 1: Lead-time of a product

The lead-time curve of a product can be seen in Fig. 1. The original lead-time curve is blue. The users determine an *l* limit,

which defines the maximum deviation. The deep blue and the orange are the upper and the lower bound respectively. The l limit is 30% now. if the value is above 30%, what the upper limit shows, we will reject the lead-time. Similarly, if the value is below the 30%, what the lower limit shows, the lead-time is rejected. The value is the real value in Fig. 1, but since we are using prediction of the cubic regression, the value means the lead-time we got from the vendor in the future. The curves should be updated within a certain period.

IV. LONG SHORT-TERM MEMORY

Long Short-Term Memory (LSTM) networks proposed by Hochreiter and Schmidhuberare are a powerful tool for modeling sequential data due to their unique ability to capture long-term dependencies. [22] Unlike standard RNNs, which struggle with remembering information over long sequences, LSTMs have a special structure that allows them to store information for extended periods. This is achieved through the cell state and gating mechanisms that regulate the flow of information. LSTMs control what information to add to the memory, what to output, and what to forget, enabling them to capture long-term dependencies.

An LSTM unit is composed of three main elements:

- Cell state (C_t) : The memory of the network, responsible for preserving information across time steps.
- Hidden state (H_t): Represents the output of the LSTM at each time step.
- Gates: These control the flow of information into and out of the cell state.

LSTMs have three types of gates: (1) forget gate, (2) input gate (3) output gate.

The forget gate f_t controls which part of the previous cell state should be "forgotten" at the current time step. It is computed as:

$$f_t = \sigma\big(W_f[h_{t-1}, x_t] + b_f\big), \tag{3}$$

where, W_f are the weights for the forget gate, h_{t-1} is the hidden state from the previous time step, x_t is the input at the current time step, b_f is the bias term for the forget gate, and σ is the sigmoid activation function, which outputs values between 0 and 1. The value 0 means forget calculation, while 1 means keep calculation.

The input gate i_t determines which new information should be added to the cell state. It consists of two parts: an input update gate and a candidate value. The input gate is calculated as:

$$i_t = \sigma(W_i[h_{t-1}, x_t] + b_i), \tag{4}$$

The candidate cell state $\widetilde{C_t}$, representing the new information to be added to the memory, is computed using a hyperbolic tangent function:

$$\widetilde{C_t} = \tanh\,(W_C[h_{t-1}, x_t] + b_C, \tag{5}$$

where W_i, W_C are the weights, b_i, b_C are biases, for the input gate and candidate cell state.

The cell state is updated by combining the forget gate, the previous cell state C_{t-1}, and the input gate with the candidate cell state is:

$$C_t = f_t \cdot C_{t-1} + i_t \cdot \widetilde{C_t} \tag{6}$$

The forget gate f_t determines what to remove from the previous cell state, and the input gate i_t decides what new information to add to the cell state.

The output gate O_t decides which information from the cell state should be passed to the hidden state. It is computed as:

$$O_t = \sigma(W_o[h_{t-1}, x_t] + b_o), \tag{7}$$

where the hidden state h_t is calculated by applying the hyperbolic tangent function to the updated cell state and multiplying by the output gate:

$$h_t = O_t \cdot \tanh\,(C_t) \tag{8}$$

Having summarized the LSTM process, the three gates work together to control the flow of information in the LSTM cell:

1) The forget gate f_t decides what part of the previous memory C_{t-1} to keep.
2) The input gate i_t updates the cell state C_t by adding new information $\widetilde{C_t}$.
3) The output gate O_t determines what information from the cell state should be sent to the next time step's hidden state h_t.

The LSTM architecture can be seen inf Fig. 2. Using LSTM, three different scenarios were performed. First, individual product prediction was made. The product family prediction was the second one, while vendor prediction was the third one. In the case of product, the lead-time value is trivial. In both the product family and the vendor case, the lead-times are aggregated with average. This means that the average of all lead times for each given product family and supplier was taken.

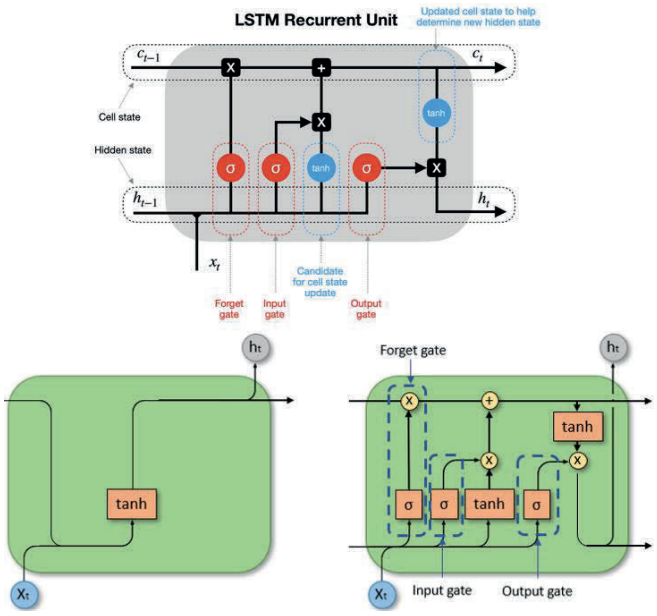

Figure 2: The basic operation of LSTM

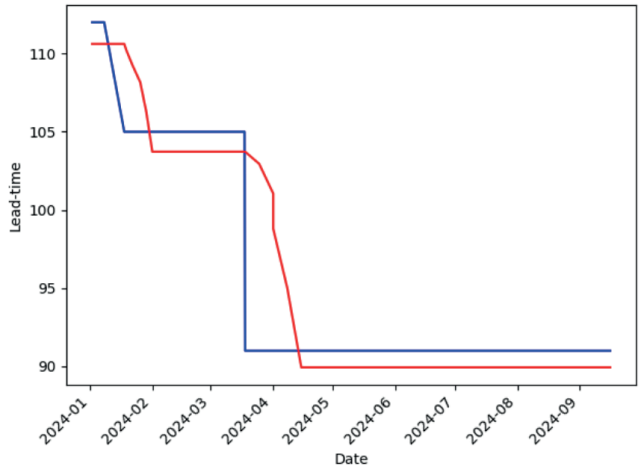

Figure 3: individual product LSTM result

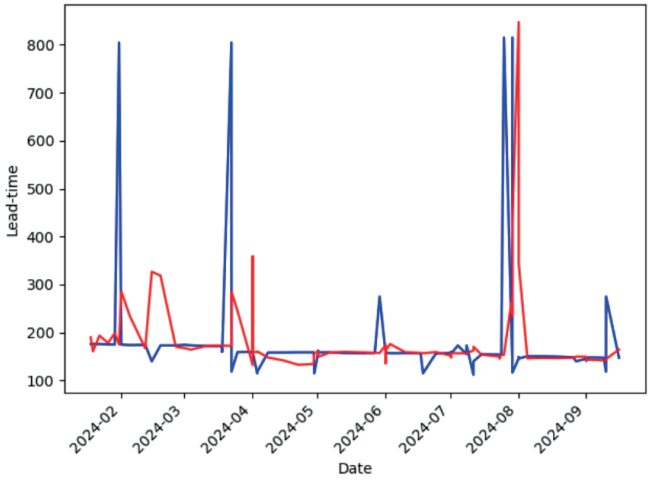

Figure 4: product family LSTM result

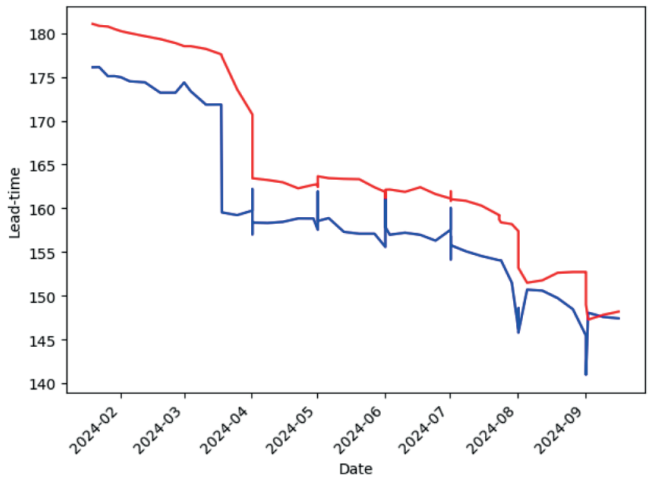

Figure 5: vendor LSTM result

All three scenarios used 40 epoch during the learning process, and the results are summarized in Fig. 3, Fig. 4 and Fig. 5 respectively. The red lines are the predicted values by LSTM, while the blue lines are the original values. In each scenario, the mean absolute errors are 2.1629, 75.9111, and 5.4412 respectively.

V. CONLUSION

In this paper, we analyzed lead-time optimization within a manufacturing company using SAP systems. By leveraging polynomial regression (specifically cubic regression) and Long Short-Term Memory (LSTM) neural networks, we demonstrated that predicting and evaluating lead-times can significantly improve procurement efficiency. According to results, the individual product and the vendor average lead-times are satisfactory, however, the product family lead-time error is a little bit high. The models can be improved, several scenarios can be performed using number of epochs optimization or hyperparameter tuning. However, these methods enabled the classification of lead-time data into credible and non-credible categories, allowing for timely intervention when discrepancies were identified.

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Databases, interfaces, data driven planning in ERP environments

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***Abstract*— An ERP system is an integrated environment that utilizes a central database. Based on my research in the field of database engines (SQL, NoSQL, and in-memory), I recognized that a more powerful architecture could be developed, allowing for optimization in terms of performance, scalability, and flexibility. To achieve this, a company requires better human resources, as well as specialized interfaces between components and parallelism. I conducted research on the SAP ERP system regarding parallel possibilities and data communication between parties. The REST capabilities of SAP present a challenging technology without a sustainable environment for implementation. I proposed a theoretical framework and built a prototype as evidence of this need. To enhance performance indicators and to track real-world changes, I developed an arrangement and structure to collect, aggregate, and evaluate data instantly using the Internet. The storage of the collected data, along with its usability and interconnectivity led to alternative applications of Big Data or data lake-like solutions. The whole designed architecture is driven by the data.**

Keywords*— *ERP, NoSQL, Data lake, digitalization, organizational interest, REST framework, IoS

I. Introduction

The ERP system is central to the day-to-day operations of any company. Earlier such software was not so critical but in today life it collects, generates the main business data and helps in planning, designing the production, logistics and many more topics around the whole business environment. In this approach, I synthesize the ERP system in a data-driven design. I collect the operation of each function into data stores by sensing signals from the environment and processing them after enriching the internal information.

II. Databases

The early ERP systems primarily focused on managing data through tables and their relationships [16]. However, modern ERP systems have evolved to incorporate more advanced, contextual approaches. Data is now managed as objects (such as invoices or employees), following principles of object-oriented architecture. Core concepts of OOP (Object-Oriented Programming) like abstraction, encapsulation, inheritance, polymorphism, and event-driven messaging are now integral to these systems. SAP, for instance, has introduced a Business Object layer, which operates above the traditional table-based model and integrates business objects through a fully object-oriented perspective.

In my research, I have explored the extent to which a simplified ERP system could be implemented using an object-based or object-relational database [12]. My findings indicate that this approach can enhance data access speeds at the application level by bypassing an entire development layer or embedding it within the object itself (encapsulation). However, this technique may negatively impact report generation speed. To address this, I developed a method that employs separate collector objects to optimize performance. Moreover, using an Object-Relational Database Management System (ORDBMS), object identification can be efficiently implemented through alternative methods, while also leveraging indexing for improved performance. My research has investigated the feasibility of implementing a simplified ERP system utilizing either an object-based or object-relational database [12]. I have demonstrated that this methodology could enhance data access speeds at the application level by effectively bypassing a complete developmental tier or integrating it within the object (enclosure in a unit). However, it is important to note that this technique may weaken report generation efficiency. My proposed method addresses this issue by employing distinct collector objects designed for achieving performance gains. Furthermore, leveraging Object-Relational Database Management Systems (ORDBMS) allows for alternative methods of object identification and facilitates indexing capabilities. In my experiments, I advanced the data storage process by operating directly on objects, bypassing the traditional database management system. This was achieved by employing the object storage technique, as outlined in a previous study, and directly placing the objects onto the storage layer (i.e., disks). I conducted practical tests using a Ceph disk environment [2], a highly efficient open-source technology known for its redundancy, speed, and configurability, making it suitable for enterprise settings.

In my implementation, I utilized simple objects, storing their data as storage objects while defining their type (class), interface, inheritance hierarchy, and attributes as metadata. These metadata were then linked to the objects, allowing for efficient searchability and rapid access. The assembly of data and features at the code level—referred to as unit encapsulation—was addressed by creating the necessary classes and objects at the program level, while data retrieval occurred from the object storage layer when an object was instantiated. The Ceph environment, along with Python code, was employed for both research and testing. The prototype demonstrated that, in contemporary computing environments, this approach can provide a sustainable solution with enhanced cost efficiency and performance.

Many directions have been explored to ensure continuous service, but the best approach is the so-called CAP theory (Fig. 1). This theory was presented by Eric Brewer at the PODC conference in 2000 [3]. Essence: availability and consistency in a distributed system. It has been demonstrated that in distributed systems, only two out of the three core system characteristics can be achieved simultaneously.

These characteristics are as follows:

- Consistency (C)
- Availability (A)

- Partition Tolerance (P)

Figure 1 – CAP theory (Brewer)

Traditional database consistency is represented by the ACID properties, which stand for Atomicity, Consistency, Isolation, and Durability. In contrast, a newer paradigm known as BASE (Basic Availability, Soft State, Eventual Consistency) has emerged, specifically within the context of the CAP theorem. While ACID emphasizes strict consistency, BASE allows for more flexible consistency models, with a focus on availability and eventual consistency over strict transactional guarantees. For transactional systems such as ERP, the ACID model is typically preferred due to its need for precise data consistency and reliability. However, in systems like e-commerce platforms, availability is often prioritized, allowing for looser consistency models under the BASE framework. In such cases, BASE can serve as a viable alternative to ACID [22].

Moreover, NoSQL (Not Only SQL) databases are worth considering for ERP systems, particularly given their flexibility in data storage and retrieval. Common types of NoSQL databases include key-value stores, column stores, document stores, and graph databases. Through my tests, I have explored these different database models and identified certain general characteristics that can be observed in basic, integrated systems.

- a common database: a database where everything has a place
- internal integration: modules can exchange data across tables without separate codes, thus reducing the need for communication
- consolidation of component installations: by placing functionalities side by side, additional communication costs can be achieved.
- higher consistency: no synchronization and even multiple data capture (lower error rate)
- higher reusability: as functionalities are placed side by side, by designing a given basic function, several modules, applications, and components can execute individual routines
- data access: as different modules, and components need to access the same routines (functions) and data, a detailed and extensive system of access control and authorization needs to be developed
- centralized technology functionalities: this includes job management, printing, database functionalities, change tracking, interface design (in some cases development environment)

These features are very efficient and work well for a small system, although the issue of data access can cause a lot of problems. Today's ERP environment is already built according to ERP II compliance, which means several separate components. My NoSQL studies have shown that it is not worth buying monolithic, large systems, but smaller, targeted systems with functionality, even designed and developed by the company's own developers. This step allows not only to build the applications according to the purpose, but also to use the appropriate database manager. Of the 4 main NoSQL database directions mentioned above, I will first address three, and then column store, or column-oriented data storage, separately. Below, I present a very useful categorization of NoSQL databases, in which the author has generally shown that RDBMS is not a one-size-fits-all solution, even if it is a very useful and working solution [1].

TABLE I. NoSQL DATABASE CATEGORIZATION

DB kind	*Performance*	*Scalability*	*Flexibility*	*Complexity*	*Functionality*
Key-Value stores	high	high	high	none	variable (none)
Column stores	high	high	moderate	low	minimal
Document stores	high	variable (high)	high	low	variable (low)
Graph databases	variable	variable	high	high	graph theory
RDBM	variable	variable	low	moderate	relational algebra

As demonstrated in Table 1, most databases provide a more flexible environment, enhancing performance while offering increased scalability. Among these, graph databases are particularly noteworthy, as they excel in handling highly complex applications with minimal performance degradation, regardless of data volume—an advantage not typically observed in traditional RDBMS systems. Below, I will provide a brief overview of the capabilities of the three primary database techniques.

A. Key/value store

This type of database manager is relatively simple, as it stores a single value for each key. Such databases can achieve read speeds that are 10-15 times faster and write speeds 6-8 times faster than traditional RDBMS systems [6]. However, they lack complexity and advanced features. Despite this simplicity, complex keys can be utilized to represent relationships between tables. In an enterprise management context, this type of database is particularly useful for verifying the existence of specific records and retrieving their details, such as master data storage, quick searches, and custom configurations. It also functions effectively as a cache, being well-suited for storing searchable data, especially when managed with indexes or hash tables. For applications like CRM systems—such as managing customer data, shopping carts, and price lists—this approach is advantageous. Care should be taken to structure taxonomies properly to ensure fast filtering and ID searches. Based on my tests, I would also recommend this type of database for authorization, access management, and identity management (IDM) systems, as it provides rapid query responses and is highly available due to

its distributed architecture. Additionally, my tests revealed that the size of data being processed or modified is typically small, making propagation in an "eventually consistent" environment sufficient. However, I do not recommend this solution for hierarchical storage, such as the Microsoft Windows registry, as it may not be well-suited for such use cases, but inventory tracking, product lookups, or customer sessions where rapid access to small, discrete pieces of data is necessary can be beneficial.

B. Graph database

Graph databases are built on the basis of graph theory, with the aim of managing the information that can be described in this way in a very efficient way. Graphs are usually a network of nodes (or vertices) and edges, in some cases the edges are directed, in which case they are called directed graphs. In graph databases, so-called property graphs are usually used, which assign properties (attributes and meta information) and labels (for grouping) to nodes and edges. Most problems can be described by graphs, so they have a very wide range of applications from naturally occurring networks, links, paths to logistic data, access management, fraud detection, process descriptions, next step recommendations. My observations are that in most cases we think in graphs in a business context, so a graph database is also a useful tool for storing, managing and retrieving data. Tests show that solving complex tasks is much faster and easier with graphs than in an RDBMS environment. However, it requires a graph-like approach, thinking, cannot handle binary data very well, schema design is not flexible [23].

I constructed a graph database based on fundamental ERP tables, consisting of two types of nodes: customers and products. The edges between the customer and product nodes represented the "orders" relationship, along with associated quantity information. This model allowed for efficient querying of order lists, with the capability to filter by product, customer, or time period. The object model can be effectively represented within a graph database, as it enables the implementation of relationships between objects. Specifically:

- Inheritance (IS_A): Relationships between objects as nodes are represented by the "IS_A" notation, signifying inheritance between different object types.
- Instantiation (INSTANCE_OF): Classes and objects are modeled as nodes, with their properties and descriptions expressed as labels or attributes. The instantiation relationship, denoted by "INSTANCE_OF," illustrates that an object is an instance of a particular class.
- Aggregation (HAS_A): Aggregation, a form of association between objects, is depicted in the graph. It supports one-to-one, one-to-many, and many-to-many relationships, which are undirected. Additionally, cardinality (e.g., 0:1, 1:n) can be defined within this relationship to specify constraints.
- Composition (PART_OF): This is another form of association, where the existence of associated objects depends on the composite object. For instance, if a car (the composite object) ceases to exist, so do its components, such as the engine and wheels.

Accordingly, using my previous results, the data of an ERP functionality can be stored in a graph database. However, this is only a theoretical proof, in practice it is not worth implementing a complete ERP in a graph database. However, it is a very useful tool for managing HR organizational information, for planning and managing the use of routes and warehouses in the case of supply chains, and for controlling the production and delivery of raw materials to suppliers, so, it is also recommended for interconnected data usages.

C. Column store

It is called columnar, or column-oriented database. My tests were performed on databases set up in an enterprise environment (SAP HANA 1.0 and 2.0; RIAK database), which gave me the opportunity to test larger amounts of data and to detect operational problems.

It is clear from the literature that transactional (such as ERP), i.e. OLTP (OnLine Transaction Processing) systems manage most tables based on keys. These systems manage and store data in an application-oriented way (including, of course, task- and transaction-oriented), i.e. billing, maintenance, purchasing. The analytical systems are not task-oriented but object-oriented [4], the analysis does not focus on the process (e.g. purchasing) but on the things or objects involved (product, trader, order). Column-oriented databases or data storage are useful for storing and managing such data, i.e. for performing analytical tasks. There are three important (but simple) differences in column-based database implementations compared to RDBMS: (1) where there is no data, there is no field stored, indeed there is zero byte occupancy; (2) any number of columns, fields can be defined; (3) since fields are stored as key-value, there is no need to predefine a structure, but can be any field name, even generated.

I conducted empirical tests using a column-family database by implementing the open-source HBase environment. In this setup, I developed a data loading process integrated with SAP through Python, following the creation of a basic demo data model. The testing demonstrated that, after a straightforward and rapid setup, it is relatively easy to construct queries and design interfaces for interacting with the database. Additionally, the system proves to be cost-effective to maintain and operate, provided that the organization possesses sufficient internal expertise.

D. Others

SAP HANA database manager is in reality an in-memory relational database manager, capable of both row- and column-oriented storage. I was able to perform investigations and baseline tests with several systems, which brought up architectural and conceptual issues. Its positioning is in the NewDB category, although it does not meet the criteria, but it intends to perform OLTP and OLAP functions at the same time. It is not considered as a NoSQL database. As it is not a true distributed system, its performance is mainly concentrated on the central database server, which is vertically scalable. OLTP functionalities (SAP S4H, SAP for HANA) make good use of in-memory services when business logic is written or translated to the database layer. In addition to evaluating SAP HANA, I conducted usability and technological tests on an alternative in-memory database within an x86 Linux environment. The database in question, OmniSci, is a column-oriented system that leverages GPU (graphics processing unit) computation rather than traditional CPU cores. Although my testing was limited to basic functions, the column-oriented RDBMS demonstrated high efficiency. The data organization within OmniSci is

particularly noteworthy, as it partitions table rows into fragments of a specified size, divides them by columns, and further splits them into what are referred to as "chunks" [5]. This technology proves valuable when queries can be fully parallelized, meaning that the tasks and associated data are efficiently distributed to the GPU processors. Such parallelization is particularly suited not only for typical data warehouse analysis but also for handling high-speed, parallel data streams, such as those generated by IoT devices. It is also useful for processing location-based data and image analysis, allowing for identity and similarity testing in existing models. While these applications may only be tangentially related to ERP systems, they address increasingly prevalent technological demands.

As a conclusion of the database access driven component design that I introduced, the integration level of an ERP system can be changed from the single database to several cooperatively working and communicating components.

III. Organization, Education and Digitalization

The modern age is one in which we are increasingly seeking to leverage IT within the enterprise, not only increasing the use of systems but also transforming processes and thinking. This initiative is often framed under the concept of digital transformation. It may seem unexpected to address non-technological issues related to information technology; however, as highlighted in the introduction, the level of operational efficiency and software adaptability is significantly influenced by the workforce. Consequently, staff members can either facilitate or obstruct sustainability and innovation efforts. Historically, when IT support was limited to a few discrete tasks, and later evolved into a set of integrated systems, the skills required from personnel interacting with software were relatively specialized. It became evident that some individuals adapted to the assistance provided by applications, while others struggled or rejected such support. Initially, separate systems were deployed for singular tasks; subsequently, the integration of these systems allowed for parallel usage. Over time, this led to the development of interconnected processes and functions among various systems. Later, they could build processes using the functionality of different systems and the need for workflow and later service-based environments emerged. [24] I have shown how version changes, interface changes, affect the employees, what their needs are, which need to be investigated to achieve the right acceptance by as many of them as possible. I also examined end-user and operator attitudes in surveys I conducted in several companies, mainly during ERP implementations and version changes.

For these I recorded applicable and measurable KPI directions. As I did not work in the human capital department of any of the companies, the measurement was anonymous and based on a probe. At the same time, it can be shown that human capital professionals need to build and maintain trust in their employees, because if they feel that the recorded data could be used against them, the value of the measurements will be rapidly reduced. Of course, Maslow's pyramid [7] can be quoted, as it clearly states the basic need of the individual to get to the point of being accepting and even constructive. More far-reaching and complete is Ken Wilber's integral view [26], where the individual views the world from internal and external perspectives, as well as from a single or multiple viewpoint. It is also a response to the fact that measurements rarely give a true picture of the inside (the self and the what perspective) unless a suitably complex set of psychological questions is used, but that these require not only great expertise but also complex thinking and a lot of time to compile. In my survey, we also tended to focus on external data, but we did not really know what was going on inside. In the survey I conducted, we also focused more on external data, but I also tried to take a broad look at the internal trends. The indicators included both objective and subjective acceptance criteria, as well as openness questions. I did not include all the questions originally planned for the survey because, in my experience, a questionnaire (Fig. 2) brought in by an external examiner with so much personal data is only filled in if they are sure that it will not affect the employee's classification. From a basic innovation point of view, the following attitude tests would have been good: resourcefulness, optimism, confidence, adventurousness, adaptability, drive, tolerance of uncertainty.

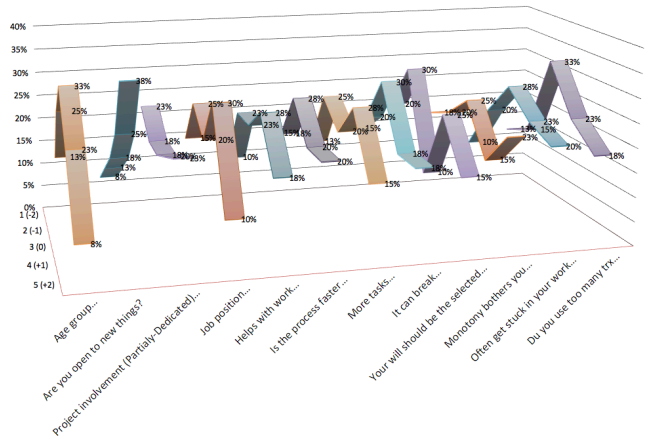

Figure 2 - Project participation and openness

The survey (Fig. 2) showed that it is very important to select professionals for the project team not only on the basis of knowledge, but also on the basis of openness and innovativeness, because the internal structure of the project organization has a strong influence on the outcome. In addition, it is important to provide continuous positive feedback and to listen to employees from an emotional point of view (especially in terms of their voices, whether positive or negative).

From what I have observed on projects and from surveys, I have been able to show that for younger workers, attitude and having their needs met matters a lot, because then they can focus on the profession. In addition, from a professional point of view, it is worth hiring a young employee from a place where they have been trained in the functionality and use of ERP systems [14]. Such training is particularly useful for developers, because they already produce interfaces that meet more modern requirements and thus speed up the innovative transition. With good communication, they can be engaged and highlighted to mentor and guide senior colleagues on specific topics [13].

I have had the opportunity to observe, participate, and even teach in training sessions in various companies. [27], examining attitudes to projects through training, gives a sequence of criteria: active leadership and participation by top management, Commitment to implementing change, Full involvement of people in key positions, Involvement of the whole company, Continuous reinforcement, Credibility of the trainer, Peer involvement, Enthusiasm. These criteria can be

treated as essentially classroom training. According to [8] the digital learning the smartphone and other mobile devices are more common in the people living the universities and starting to work. The paper also describes the behavior and the classification possibilities of the students by checking the referred eLearning topics. However, in my observations, I have noticed that companies are investing a lot of energy in computer-assisted e-learning trainings. Workers take the courses and pass the exams, but about 3-5% of the information is retained because most of the information is not relevant to their field, and it is compulsory training and not done out of the free will and desire to learn. The training on the use of ERP software is usually done in 2 layers: (1) the vendor gives lectures and exercises to project participants and later (2) the project team gives end-user training to their own colleagues. In my research, this is usually not enough. The majority of the project team learns the major features and can perform them but in reduced quantities.

The most stable knowledge is gained by building a structure that demonstrates the basics before use, which is easy to master. But the details are presented together, by working together, by demonstrating, by arousing the interest of the student or worker from the practical side, and by asking for immediate practical feedback. At the end of a project, it is worthwhile to retrain so that the knowledge can be put into practice in a system, combining experience with knowledge, because then the employees can really ask questions, bringing in their own problems, which helps to improve and deepen understanding. For new workers, mentoring is important, because reading dry material does not create a desire for real understanding. “Mentoring within education is different from mentoring practiced in every other industry” said Herman Stewart, a mentors’ mentor at ECNM (Every Child Needs a Mentor). In the research [9] these are also discussed separately but the similarities and differences are emphasized. “Mentoring increases student engagement with the university”. Mentoring provides advantages across all levels of educational engagement, encompassing early childhood education through to post-doctoral training. Companies’ organizations in the 21st century are experiencing a rapid rate of change on that the mentoring programs that are evaluated and analyzed can help address this. The mentoring at a company helps after the study to be familiar with the real process, application and related topics. It is necessary to first show, in a guided way, the processes, the why, how it works, and then where to find detailed descriptions, even e-learning materials. As I wrote, an advantage is ERP experience in practice gained in university education [20].

Digitalization is a natural challenge for organizations, for the designers and managers of organizations, and for individuals. According to the [10] the digitalization is a term for describing the impact of digitization. As the article says the digitization is “increased availability of digital data enabled by advances in creating, transferring, storing, and analyzing digital data”, so moving from analogue to digital data, or even implementing an ERP system. The process itself is not just about introducing IT or digital support in most areas, but more about transforming and renewing mindsets. Importantly, stability is not the right direction for such organizations, nor is innovation, as it is not a fixed state. Rather, it is flexibility and resilience that must characterize an individual in order to be able to accept and participate in digitalization, and even to propose innovations and innovations independently. Also included in my studies were the aforementioned openness, adaptability, and freedom of choice. These can help innovative attitudes. They need to be allowed to look further afield, not to look to the leader for direction, but to dare to create. This requires not just competitive targets and KPIs, but even a sense of accomplishment rather than happiness, a sense of satisfaction, so that employees can keep performing. [25] Automation has a major impact on the organization, which is increasingly supporting machines, even in decision-making situations. Professionals should be encouraged to look for, find, and solve automation opportunities in their own field. This is where education comes into play, as it is measurable who in the organization has the drive, adventure, ingenuity, and willingness to improve. For them, it is definitely worth making more modern literature available (e.g. in the form of Udemy, and O'Reilly courses). This will provide an opportunity to help the company move forward.

When changing the organization, it must be considered that a huge emphasis must be placed on the branch of IT that can already work with existing data and serve all areas. The data governance (like data warehouse, Big Data) functionalities and processes mentioned later should also be incorporated into the central solutions. Innovation requires that the interrelationships between existing legacy systems be captured and shared across disciplines (in the light of security considerations). Further context can be sought over data from these systems at the data mining level. Another driver of digitization is the convergence of business experts and IT within the organization. In my experience, as confirmed by data collection in several companies, IT professionals, specifically developers, understand different business problems, concepts, and relationships faster than business professionals understand IT relationships. Therefore, it makes sense to place a team of developers in a business environment, with the experts, to achieve future-oriented results together.

IV. Acting on the Market Changes

My research primarily investigates the dynamics of existing and emerging relationships with business partners, encompassing technology suppliers, including both hardware and software collaborators. It is imperative to establish a robust ecosystem for engaging with and managing these partnerships, aimed at fostering shared expectations and facilitating effective communication. Changes within the business landscape are mirrored in partner relationships and are also influenced by modifications in the IT tools they provide. In response to business transformations, I advocate for the implementation of Internet of Things (IoT)-type monitoring devices, which can process data to support decision-making processes or enable automated interventions. I refer to these sensors as the Internet of Sensors (IoS), illustrated in Fig. 3 through a schematic model. These sensors function not only as data-collecting hardware components but also engage in data analysis as compact applications, transmitting detected signals efficiently. The upper layer operates conventionally within the IoT paradigm.

I have developed web-based data retrieval pattern applications utilizing Python that emulate sensor functionality by collecting data and relaying change signals for subsequent analysis. Among these applications is a stock market analyzer designed to monitor significant fluctuations and indicate when intervention may be warranted, alongside another tool that tracks variations in wage levels. As depicted in Fig. 3, my hypothesis posits that this data is integrated into a Big Data

environment, from which IoS applications extract foundational information necessary for constructing their models; concurrently, the collected data is archived here to inform decision-making or facilitate preparatory decisions aligned with the established model.

This discourse expands upon the concept of digital transformation by incorporating a more extensive array of business, market, and ecosystem "sensors" to furnish real-time feedback and facilitate dynamic decision-making within an ERP.

Figure 3 - IoS (Internet of Secsors) logicat architecture

While many practitioners perceive Big Data and data lakes primarily as supplementary resources for ERP systems, a comprehensive review of scholarly literature indicates that these components can indeed function synergistically in both directions across multiple dimensions—technical, semantic, and organizational. [21]

My methodology integrates several advanced technological elements:

- Data Collection Sensors: The utilization of external data sources, including job portals, stock exchanges, and transportation networks, augments internal ERP data with real-time market intelligence.
- Data Lake: Serves as a centralized repository for both structured and unstructured data from varied origins, thereby supporting holistic analysis.
- Big Data Analytics: Facilitates the identification of patterns, trends, and anomalies while yielding insights that inform both long-term strategic planning and immediate operational decisions.
- ERP Integration: Enables the reintegration of analyzed data back into the ERP system to instigate actions or present recommendations to decision-makers instantaneously.

I have developed web-based applications employing Python for querying data patterns that act as sensors collecting information and transmitting change signals for subsequent analysis in prototype form. These include a stock market analyzer designed to monitor significant fluctuations and signal potential intervention points, alongside another application tracking wage level changes. Central to my theoretical framework—as depicted in Fig. 3—is the premise that this data is funneled into a Big Data environment from which Internet of Services (IoS) applications extract foundational information to construct their models; concurrently, the collected data is archived here to facilitate decision-making aligned with these models. This approach exemplifies how real-world metrics such as HR salary benchmarks or stock exchange indicators can be seamlessly integrated into decision-making processes within an ERP environment. The forthcoming step involves broadening the spectrum of available data sources while enhancing the scalability of these prototypes; this could potentially involve leveraging data pipelines as well as integrating more sophisticated analytics and machine learning models for predictive insights. Technologies associated with Big Data—such as Apache Kafka or real-time processing engines like Apache Flink or Spark—could significantly contribute to achieving real-time event handling and analysis. This advancement would transition your solution from mere decision support towards proactive and dynamic decision-making informed by market fluctuations, employee performance metrics, and other external signals. Such an approach could lay the groundwork for adaptive, data-driven business management across diverse sectors.

V. Data Management

In my approach about the data-driven planning in ERP environments I am using data warehouse systems and data lakes or Big Data environment for data preparation and cleaning. Data Warehouses are structured, reliable systems designed for historical reporting and in-depth analysis. They're useful for ERP environments where structured, transactional data is crucial for making decisions and planning. They provide the stability needed for financial reporting, supply chain analytics, and KPI tracking. On the other hand, Data Lakes offer flexibility by handling raw, unstructured, or semi-structured data, which could include IoT data, social media inputs, or machine logs. These can be useful for more exploratory analysis, advanced machine learning models, or predictive analytics in ERP systems. Data lakes allow for a broader range of data types, which can feed into planning and decision-making processes. They are particularly useful for organizations looking to integrate various sources of information and achieve more nuanced insights. Big Data is the broader concept that includes not only storage but also the frameworks, processing, and analytical techniques for managing massive datasets from multiple sources. Although the functionality of Big Data is increasingly positioned within the realm of Business Intelligence due to the management of large volumes of data, it is becoming progressively vital for organizations not only for the handling of individual project data but also for their overall governance. [28]. However, combining these two approaches – structured analysis from data warehouses and flexible data exploration from data lakes and big data systems– can offer a hybrid model, which provides the governance and performance benefits of warehouses with the flexibility of lakes. The big data environment follows a strong and scalable approach in my bi-directional solution by treating the ERP as a master data source while enriching it with data from IoT systems (os IoS information), applications, and other sources. This allows for a richer dataset that can give more accurate and detailed insights when performing analytics, predicting trends, or generating real-time directives. The big data enriches the ERP data with external sources (such as IoT devices) and adds a layer of complexity but also value. we can derive new insights and use cases, like predictive maintenance (via IoS data) or dynamic demand forecasting. Our big data architecture should also support streaming data pipelines to achieve real-time

Processing. Apache Kafka or similar technologies can help handle real-time data feeds. In my approach, it is essential as I need fast feedback on the ERP from the big data processing results.

VI. Interfaces

To establish connectivity between various systems and supplementary applications, the necessity for interfaces is paramount. SAP, a widely utilized ERP system, has developed numerous technologies built upon the RFC and BAPI solutions [17, 18]. A notable advancement in this domain is the support for Web Services alongside foundational implementations of Service-Oriented Architecture (SOA) [16]. As the market evolves, new, widely accepted interfaces and accelerated technologies continue to emerge. Primarily, Web Services communicate through XML schemas; however, contemporary programming languages and environments are increasingly adopting JSON as the data format for information exchange.

I have examined the requisite steps to create a similar supportive environment within SAP for enabling REST APIs. From a comprehensive technological perspective, it is feasible to both create and consume REST APIs within an SAP system; however, there exists a deficiency in the management and support infrastructure. To develop such an environment, several abstract considerations must be articulated:

- Integration Requirement: The solution must facilitate both inbound and outbound REST API calls while accommodating fundamental CRUD operations (GET, POST, PUT, DELETE) via HTTP methods. It should support data exchange in both XML and JSON formats.
- Authentication & Security: At minimum, Basic Authentication should be implemented to ensure secure access (HTTPS configuration is managed at the system level).
- Data Handling: It is essential to convert SAP data (BAPIs, IDOCs, and other entities) into appropriate formats (JSON) and vice versa. Efficient error-handling mechanisms and logging capabilities should be established for enhanced traceability.
- Version Management: Incorporating API versioning would provide valuable service within this solution.

My primary focus has been on data handling aspects. In terms of Web Services, SAP provides SOAMANAGER; however, it can be expanded upon by integrating the following conceptual enhancements:

- Service Definition and Routing: The SAP web server—termed Internet Communication Framework—should be augmented with new services utilizing ABAP classes.
- Monitoring and Tracing: While SOAMANAGER offers analogous functionalities, it is imperative that responses are captured beforehand for logging purposes (including payload details, timestamps, endpoints, statuses, and error specifics). This information can subsequently be integrated into SOAMANAGER.

In accordance with my outlined requirements, I have devised a rudimentary prototype environment within SAP primarily focused on supporting REST API management. To translate theoretical concepts into practical tools effectively requires addressing additional topics such as message serialization (wherein REST APIs may be serialized into IDOCs or alternative message types), enhanced error handling (extending existing error management protocols for ALE), or event triggers (to generate notifications regarding issues or to restart failed processes). Herein lies a comprehensive collection of requirements aimed at implementing new interface technology within standard ERP frameworks and centralized management tools. In relation to SAP specifically, I succeeded in creating a basic prototype that addresses part of these requirements. The subject contains still future work.

Beyond the interfaces, parallelism is also a requirement to build such a data-driven environment. The application-side elements involved in the interfaces are modular. This means that connection, data processing, data reading, and data handling routines can be implemented as functions, procedures, or even object methods. In different ERP solutions, modularization units use different levels of granularity or granularity [11], which can range from technical module elements to business-level functions. In most cases, these modules can be reused or even reimplemented in an object-oriented environment. Using dynamic development paradigms [15], individual module elements can be created at runtime, thus providing more flexibility to the application and the interface. To achieve higher throughput, the environment must be parallelized. This requires parallel startup of each module, which implies data sharing, recording the state of each thread, publishing, and synchronizations. From a technological point of view, the communication of parallel processes can be done through memory, but if the application is running on multiple hosts, other techniques must be used. In other words, parallelization must perform the following tasks in an environment:

- Use independent module elements that can be considered atomic
- Depending on the architecture, threads, and processes can be used to parallelize processes
- Provide mutual exclusion to manage shared resources
- Synchronization points must be able to manage shared resources to exchange messages between processes (in most cases rendezvous)
- Acceleration or efficiency gains

Data decomposition can be dispensed with here, as the individual tasks are available as module elements. However, a higher level of decomposition is necessary, as it is important to only start processing a complete data set if you need the whole in one piece, once all parts are available. This in turn results in a synchronization point again. Decomposition involves speedup, which, according to Amdahl's law, means that the total speed of the parallelized process depends on the execution time of the sequential, or module element. We have shown, according to Gustafson's law, that parallel execution results in additional communication overhead for the executing units due to the transmission of data or messages for synchronization [19]. This has implications for the practical, system-dependent design of the triple of decomposition, granularity level, and efficiency. In the case of an ERP system, the module elements run at the design level, but the underlying database layer is a separate entity and each process running in

parallel runs in a separate database session. Accordingly, mutual exclusion during database connections is performed by the database manager. As mentioned earlier, threads running on the same host can communicate either through memory or with file system elements. The same is more difficult with parallel elements running on multiple hosts. In the case of a file system, of course, we can talk about a shared file system (e.g. NFS-like), but you have to handle synchronization there too when writing a file. For parallelization, it is possible to use rendezvous, where processes have to wait for each other. Technically, I have developed two solutions for this. In one, file system flags are placed in separate files and the rendezvous site checks for each incoming process to see if all process results are present. The other solution is the database, where we can do almost the same, but in some cases, it can be simplified, because the database makes the changes to a particular data unique anyway and it does the synchronization.

I have looked at SAP systems from a parallelizability point of view knowing that the system is basically process-based and cannot run code in parallel on a thread basis. The small program snippet below shows an example of how a module element (here a function module, BAPI) can be called in another process.

```
START-OF-SELECTION.
  CALL FUNCTION 'BAPI_FLIGHT_GETLIST'
    STARTING NEW TASK 'DEMO_TASK'
    DESTINATION 'REMOTE_SYSTEM'
    PERFORMING return_flight_list ON END OF TASK
        EXPORTING
          destination_from = fli_dest_from
          destination_to = fli_dest_to.
  WRITE:/ 'RFC call started asynchrously'.
AT USER-COMMAND.
  IF sy-ucomm = 'RFC_COMPLETED'.
    WRITE:/ 'Remote data received'.
    LOOP AT it_flights INTO ls_flights.
      ...
    ENDLOOP.
  ENDIF.
FORM return_flight_list USING taskname.
  IF taskname = 'DEMO_TASK'.
    RECEIVE RESULTS FROM FUNCTION
                    'BAPI_FLIGHT_GETLIST'
      TABLES flight_list = it_flights.
    SET USER-COMMAND 'RFC_COMPLETED'.
  ENDIF.
ENDFORM. " return_flight_list
```

It is essential to recognize that the quantity of processes within SAP systems is dictated by the parameter file at the time of startup, rendering it immutable during runtime. However, mechanisms such as background and dialog processes facilitate parallel data processing. In light of these established conditions, I have developed a framework that enables the parallel invocation of module elements through parameterization, as well as the incorporation of rendezvous options. This development has demonstrated the viability of employing parallelizable interfaces within an ERP context.

VII. Conclusion

A distributed ERP solution with components separated by different types of database access, such as graph databases, key-value stores, and object-based databases, could indeed make sense, especially if the architecture is designed to handle specific business needs that benefit from these different types of data models. Here's an analysis of how and why this approach might work, along with the potential benefits and challenges. Different types of databases are optimized for different use cases, and using a "one-size-fits-all" approach can sometimes result in inefficiencies. Separating the ERP system into modules that leverage specific database types could optimize the performance, scalability, and flexibility of the system.

The "IoS" (Internet of Sensors) is a forward-thinking concept. It extends the idea of digital transformation by integrating a broader set of business, market, and ecosystem "sensors" to provide real-time feedback and enable dynamic decision-making within an ERP environment. This approach brings together several advanced technologies:

- Sensors for Data Collection: Using external data sources such as job portals, stock exchanges, and transportation networks enriches the internal ERP data with real-time market insights.
- Data Lake: Acts as a central repository for both structured and unstructured data from diverse sources, supporting comprehensive analysis.
- Big Data Analytics: Detecting patterns, trends, and anomalies, and providing insights that can help drive both long-term planning and short-term operational decisions.
- ERP Integration: The ability to feed analyzed data back into the ERP system to trigger actions or present recommendations to decision-makers in real-time.

The implementation of parallelized interfaces facilitates the management of real-time data flow in a scalable manner, thereby enabling the integration of environmental and ecosystem changes as data inputs to drive the Enterprise Resource Planning (ERP) system.

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Sustainable configuration in an SAP environment

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***Abstract*— There are several problematic points during an implementation and during the daily operation of an ERP system. To be able to create a usable and sustainable environment proper methodology should be chosen for the implementation and later system changes too. For this we made a comparison of different agile methodologies usable for an SAP ERP environment. The daily operation also requires special approaches to keep the system function and usable. The article compares the today's development directions and possible tool, capabilities in an SAP system. We have developed some recommended procedures and preventive techniques, both in theory and in practice, that can help to make the SAP ERP environment sustainable. We designed a methodology to manage bigger, template-based environments using simplified configuration and deployment efforts. Enhanced documentation theory and framework is mentioned for better traceability of changes. All these together can increase the sustainability of an SAP environment.**

Keywords*— *Customizing backup, ERP, Implementation methodologies, Agile, Generated documents, Template-based, Traceability, Dynamic interface, End-user Interface

I. Introduction

Today's companies or institutes apply an ERP solution for the daily work. Installing an enterprise-wide system is a big decision and one that can improve the quality and value of your business. Many pitfalls can be encountered during the implementation process, but an appropriate methodology will help to ensure success. The utilization of ERP extends beyond the implementation; during the operation and use further adjustments, additions, and extensions may be necessary and need to be properly implemented and deployed alongside the day-to-day work. The sustainability of such systems relies not solely on their initial design and implementation but also on continuous oversight and adherence to established protocols that provide a solid foundation for long-term viability. Minimizing changes and facilitating seamless functional modifications are essential strategies for ensuring smooth transitions. This includes flexible interfaces and of course proper documentation of changes.

In this article, I will concentrate on these key areas, delineating theoretical frameworks while also illustrating functionalities through prototype solutions where applicable. The methodologies are the basis for the introduction and subsequent operation, which is why this area is the most important in the article.

II. Implementation and Operational Methods

The significance of the initial implementation of ERP systems has been a topic of discussion since the inception of these systems, particularly emphasizing the necessity for a proactive approach to Business Process Reengineering (BPR) [1]. This article examines the principal theoretical frameworks that continue to be relevant today. Beyond individual capabilities, the success of such systems is also contingent upon users' willingness and immediate acceptance [2]. The findings indicate that the predominant factor influencing success is a collective belief and trust in the system, which is bolstered by an understanding of its utility and alignment with business expectations and processes. A critical challenge during implementation pertains to efficiency and enhancement, aspects that can further reinforce employee and stakeholder confidence in the solution. The proliferation of ERP implementations during the Y2K period already coincided with concurrent version upgrades or even ERP system exchanges [3]. This increased frequency of implementations led to a greater accumulation of knowledge regarding common pitfalls. Subsequently, it became imperative to develop and adopt methodologies aimed at facilitating successful system utilization [4]. At this juncture, SAP had begun advocating for its own Accelerated SAP (ASAP) methodology, which necessitates planning already during the tendering phase and offers estimates regarding implementation resources from a consultancy perspective. The article delineates general methodologies while elucidating why ASAP may present superior efficiency. Upon examining the ASAP methodology, it becomes evident that it adheres to a waterfall-like framework. Concurrently, the documentation, questionnaires, and training proposals produced offer significant advantages during the implementation phase by facilitating a comprehensive understanding of the system's operations, functionalities, and potential. Consequently, while it is not a universal methodology, it can be employed effectively and purposefully for specific tools.

In the context of project management, particularly beyond SAP or ERP systems, it is essential to recognize that various projects and their corresponding methodologies may not always align cohesively with the requirement and environment. A fundamental distinction must be made between the deployment of off-the-shelf products versus the augmentation through development, as well as entirely in-house developments compared to those conducted by external software firms. In instances of development, engaging in prototyping and redesigning business processes proves advantageous [5]. To establish an effective system or to sustain and enhance its functionalities, certain characteristics are imperative [6]: correctness, user-friendliness, responsiveness, maintainability, testability, and reliability.

A. General methods

In my research additionally, I have expanded upon the original set of characteristics to incorporate sustainability considerations with the followings: reusable, efficient, portable, reliable, secure, configurable, and robust. Notably included is correctness i.e. how the service responds to a given input. The list explicitly contains correctness, i.e. how the service responds to a given input. I have not included any

domain-specific functional characteristics (that require domain knowledge) in the abstract elements. Three fundamental process models can be identified: waterfall model, incremental or evolutionary development model, and component-based, or integration and configuration models.

- Waterfall model: delineates a sequence of steps: requirements gathering; system design; implementation and unit testing; integration and system testing; followed by operation and maintenance. Change management within this framework is facilitated through change requests that cannot be separately planned for cost-wise.
- Evolutionary or iterative incremental models: decompose tasks into smaller components which are then systematically planned, developed, and tested for acceptance or rejection. The advantages inherent in handling smaller parts include enhanced focus precision and manageable timelines; should any aspect prove unsuitable, modifications can be confined to limited segments rather than affecting the broader scope.
- The integration and configuration model relies on pre-existing reusable components necessitating an established framework. This approach also encompasses the creation of new components or enhancements of existing ones while allowing for configuration and integration possibilities.

In contemporary discourse, the concept of agile development is frequently juxtaposed with the waterfall model. While numerous agile methodologies exist, only a select few have achieved widespread acknowledgment. Notably, an agile approach was employed by many practitioners during the initial decade of the twenty-first century. A particularly compelling article posits that such methodologies can be effectively applied in the context of SAP system implementation and specifically advocates for their use [8]. The implementation of individual process models often exhibits a degree of variability, as both high-level planning and its subsequent decomposition into smaller components coexist within an organization's operational framework. In scenarios involving the waterfall model, agile methodologies may be effectively employed during the implementation and testing phases. Three distinct implementation strategies are delineated [7], all of which are grounded in the waterfall approach, yet differ significantly in their overarching dimensions: the parallel method (where both legacy and new systems operate concurrently), the big bang approach (characterized by an immediate and complete transition that discards the old system), and the experimental method (involving simultaneous operations where specific products and functionalities migrate to the new environment while others remain within the legacy framework). In practical applications, however, organizations tend to rigorously assess every aspect of these methods, often initiating with a substantial volume or even encompassing the entire system.

B. Special methods

In addition to conventional implementation methodologies, software vendors frequently advocate for the use of rapid introduction techniques, which diverge somewhat from the traditional waterfall model. Two principal categories of these techniques are recognized:

- Rapid Introduction: This approach is employed for the deployment of a new product within specified content and financial constraints. Its phases include initiation, installation or commissioning, and live launch. During the initiation phase, elements for implementation are identified, documented, authorized, and the foundational system is established based on predetermined conditions and content specifications. In the subsequent phase, system components are activated, data is imported, and training as well as testing activities occur. A notable advantage of this method is that extensive knowledge is not requisite; rather, it is executed by seasoned professionals, thereby ensuring a swift and predictable progression. Conversely, a drawback lies in the necessity to produce documentation (in English) for the introduction process—a resource that often emerges unplanned—and there may be instances where qualified experts with broad perspectives are not engaged due to budgetary constraints.
- "Best Practice": Leveraging the manufacturer's expertise and implementation experience, this approach provides an expedited and streamlined solution for implementation. It encompasses two levels: (1) sharing implementation experiences alongside effective optimal solutions derived from them with clients; (2) incorporating technology into the implementation process. Notably, SAP has developed specific technologies such as procedural steps and loading file structures that allow users to populate their own data into the system effectively. This methodology proves advantageous particularly for configurable solutions. When contrasted with the waterfall model, decision-making timelines become even more distinct from execution stages—though actions proceed at an accelerated pace. However, a significant limitation resides in the requirement that all decisions must be made prior to implementation; consequently, "automation" adjusts the system accordingly based on best practices. The inherent benefit of this method includes its capacity to facilitate expedited setups during initial introductions.

I have reviewed the scientific literature and the notion of "best practice" is multifaceted within the realm of Information Technology (IT). A thorough examination delineates various tools and techniques, scrutinizing development methodologies, project expectations, and specifications at a broad level to elucidate the optimal methodology for these practices [9]. This inquiry particularly emphasizes agile methodologies alongside implementation and development challenges, identifying avenues for enhancement. Two predominant trends emerge from this discourse. First, the establishment of best practices within any domain necessitates the creation of an offering system deemed superior through a meticulous evaluation of all relevant aspects, including related descriptions, documentation, scholarly articles, and experiential insights while considering numerous characteristics. Second, in any field—whether pertaining to a project or an organizational unit—individuals or groups acting with good intentions tend to deliver optimal performance and practices based on their knowledge and experiences. In software development specifically, practitioners often extend beyond this framework; leveraging data collected as per the first approach to facilitate introduction and advancement

through applications and pre-configured datasets. Such methodologies are commonly referred to as best practice techniques. However, according to the latter perspective noted earlier, it is not always feasible to definitively identify a singular best practice. The concept in [10] reinforces this notion by advocating for a pursuit of excellence without becoming overly fixated on achieving perfection. Instead, it encourages the utilization of practical solutions and tool recommendations without presuming that what is offered constitutes the absolute best option available.

C. Agile methods

Examining ERP implementations and developments, numerous pieces of literature have shown that others have already thought of agile methods during the processes. Among iterative methods and agile frameworks, the SCRUM and KANBAN methods are the most common. The framework provides suggestions, methods, and steps that must be customized according to the needs of each organization and task. The two methods are similar but have a different focus, so they should be used in completely different cases. SCRUM essentially thinks in terms of deadlines: how many tasks can the team complete in a given time? In the case of KANBAN, however, the lead time of each task (design, development, testing, acceptance) is interesting [11]. I have tried these directions with teams in organizations and the choice of the right method is clear in most cases. SCRUM can be especially well used for general developments, where the needs can be broken down at the business level into developable units and thus the completion of tasks in each cycle can be scheduled based on prioritization. This can even be the implementation and functional test phase of a project specified in a waterfall model related to an ERP system. For support tasks, however, the adaptability of KANBAN matters, since they are constantly arriving, but the tasks cannot be planned.

We find literature where it is already recommended in the early 2010s to use the agile, iterative method for SAP implementations with the SCRUM extension of the ASAP methodology [12]. When SAP opened up to the cloud world, it was forced to supplement the ASAP methodology and introduce the SAP Activate technique in 2015. However, a comparative analysis of ERP implementations from the same year does not even mention it [13]. This clearly complements the usual elements of ASAP with SAP best practice tools and an additional so-called guided configuration option. The essence of this is globalization, unification, easier general operation, and minimal deviation from the standard line. In other words, when entering the cloud environment, it makes service provider work easier if all clients operate more and more in the same way. Although SAP is one of the leading ERP software, the study [14] does not highlight or even mention SAP's own methodologies when examining agile implementation methodologies. At the same time, it shows the success factors that are important for general and agile methods. It should be emphasized that the agile methodology is generally optimized for development, but my research is also focused on how useful it is for implementation. In the case of SAP, it also appeared very early as an applied development methodology, as [15] writes about the internal software development presentation of SAP AG.

While the conventional SAP Activate methodology incorporates elements of SCRUM and KANBAN, my investigations have led me to explore additional agile tools with respect to their applicability. In scenarios involving a standard boxed product or the implementation of SAP on-premise solutions, it is imperative to adopt the waterfall approach. The rationale for this recommendation includes:

- The complexity of the system environment
- The utilization of multi-layered, closed development components
- A diverse array of tasks encompassing numerous modules and professional domains
- Integration responsibilities

Upon further examination, it becomes evident that SAP Activate employs agile methodologies predominantly during the realization phase. My research has also highlighted the necessity for a comprehensive overview and coordinated efforts beyond the agile sub-tasks to ensure that various minor configurations, settings, and enhancements are effectively integrated in terms of timing and functionality. This consideration is particularly pertinent in relation to interfaces, where connections are established across multiple layers involving several professional stakeholders. At the highest level resides the business process or logic, which dictates aspects such as the reasons behind actions, frequency, and directionality of data exchanges (both outbound and inbound). Beneath this tier lies a range of standard, configurable, and message-based solutions from partner systems alongside a compendium of technological options outlining development requirements. While development at this stage can indeed proceed in an agile fashion, it is crucial to identify synchronization points among distinct areas of expertise to facilitate collaboration on shared objectives and advance overall progress. In instances where middleware is utilized—whether as a file transfer environment or an API gateway—multiple teams become involved. Should the middleware consist of EAI (Enterprise Application Integration) tools like TIBCO or ESB (Enterprise Service Bus) frameworks, additional groups will be incorporated as another layer contributing to configuration, development, and human integration processes.

In the context of software system implementation, agile methodologies prove to be particularly effective during the execution phase. Complementary to these approaches are Domain Driven Design (DDD), Component Driven Development (CDD), Feature Driven Development (FDD), and Test Driven Development (TDD) methods. My investigation involved a thorough examination and practical application of CDD and FDD methodologies, alongside testing strategies, in collaboration with a programming team on several smaller projects.

- DDD [16]: This methodology is best applied in environments where the domain's expertise, terminology, and boundaries are well-defined. Collaboration between business experts and developers is essential for constructing a cohesive model that can be decomposed into smaller components, contexts, and interrelated elements. Such an approach enables the development of distinct components that can interface with one another. The resulting model is characterized by simplicity and clarity, facilitated by a context map. Emphasis is placed on articulating the professional core. A significant advantage of DDD lies in its capacity to immerse developers in the domain knowledge,

fostering a sense of ownership that accelerates future modifications and expansions, thereby enhancing sustainability. Moreover, DDD prioritizes comprehending customer requirements and the operational environment to harness creativity within the system development process [19].

- CDD: This approach emphasizes building modular components that function as independent units. It is particularly advantageous for user interface development. Each component represents a unique, configurable, reusable interface supported by comprehensive specifications and documentation. The use of consistent components—characterized by uniform appearance and behavior—facilitates communication between designers and developers; however, it may initially impede progress. In ERP contexts, this method allows for the employment of modular constructs along with training for autonomous components that can undergo independent modifications. Though, it is predominantly utilized within the user interface environment; however, its applicability can be broadened to encompass various other domains, one of the most compelling being the development of interfaces, especially in SOA world [].
- FDD: While requiring knowledge of specific professional domains akin to DDD and CDD methodologies, FDD accommodates larger development teams without necessitating extensive domain expertise among all members. The FDD process comprises five iterative phases aimed at incrementally constructing software: compiling a feature list; planning by feature; designing by feature; and building by feature [20]. Initial phases involve creating models from which suitable options are selected to derive functional lists—these functions may also be conceptualized as objects developed within one to two weeks' timeframes. The selection process focuses on identifying functions that yield tangible value while establishing the project's core through training aligned with DDD principles. During design phases, functions are scheduled for implementation followed by individual design efforts; thus necessitating oversight from a lead programmer or architect due to varying levels of developer expertise compared to DDD. Consequently, FDD's applicability extends across broader domains where requirements fluctuate less frequently while remaining suitable for larger teams [20].
- TDD: The formulation of test cases serves as a specification guiding developmental endeavors [18]. Tests are devised based on design parameters leading to code generation; new tests emerge contingent upon successful code functionality thereby preventing redundant coding practices. The established sequence—red-green-refactor—illustrates this progression whereby initial tests often yield failures necessitating prompt rectification before refactoring internal code essence [21]. Given this methodological framework, TDD is less suited for augmenting existing applications but rather aligns with developing new systems entirely. Each functional requirement is prepared as a test ensuring comprehensive test coverage achievable through this method; furthermore, user testing validates specification accuracy through behavioral assessment which requires extending TDD practices.
- BDD: in my professional observation, ought to be employed in conjunction with test-driven development (TDD) [22]. TDD ensures the creation of code devoid of redundancy, while BDD effectively addresses semantic expectations. In the context of BDD, we utilize characteristics for which specific scenarios are devised [17]. Users are empowered to delineate the expected output corresponding to particular inputs. Notably, Gherkin syntax was developed for business professionals, enabling them to articulate their requirements distinctly: what is given (given), what input serves as the starting point (when), and ultimately, what outcomes should arise from a specified input (then). Through this framework, we articulate business needs using industry-specific terminology within scenarios represented by behavioral characteristics, essentially functioning as test cases. Testers subsequently prepare or generate test codes that invoke the intended functionality while developers focus on implementing the actual function code. This approach is particularly advisable within an ERP environment; currently, SAP offers tools for SAPUI development. With established tests in place, it suffices to execute them during version updates, thereby enhancing the sustainability of our environment through this methodological innovation.

The cornerstone of each methodology is predicated upon the customer's ability to clearly identify and articulate their needs and envision how they would validate and assess the accuracy of the final product. However, a significant challenge arises in practice when business logic is often neither comprehensible to the customer nor does the customer express a desire to validate it through testing.

D. Related topics

As previously articulated, integration is of paramount importance; thus, it is critical to emphasize that both in the phases of implementation and maintenance, there should be a concerted effort toward developing more segmented yet enhanced solutions that necessitate an appropriate level of connectivity. The accompanying Fig. 1 elucidates potential integrations concerning data, processes, and business logic along with their progression.

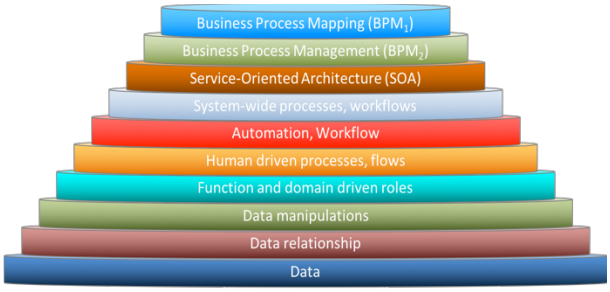

Figure 1 - Interface triangle (evolution of data management)

Historically and based on usage trends, moving upward reveals increasingly complex environments that require elevated levels of control. As previously demonstrated, a fundamental aspect of integration lies in the necessity for interfaces to be defined and operated from a business

perspective to ensure sustainability. From a technological standpoint, it remains unclear how professionals establish these connections. The inclusion of two Business Process Management (BPM) elements in the Fig. 1 serves to differentiate between mapping and control functions. These two components coexist symbiotically and can almost be regarded as dual facets of the same phenomenon.

In addition to integration, managing changes emerges as a priority area concerning sustainability considerations. In the context of SAP systems, this encompasses upgrades, Unicode migrations, S4 conversions, and transitions to SAP cloud solutions. Through comparative analysis grounded in documentation and project experiences across individual operations, I have identified key insights. The principal challenge and source of delays within modification projects stem from the management of customer-specific codes (such as copies, additions, and bespoke developments) alongside the volume of alterations made to standard SAP objects. I rephrased the delay within modification as *variation buffer*, as it describes a mechanism that absorbs or mitigates changes before they propagate through the system. The subsequent Fig. 2 presents such a comparison with respect to version changes and S4 migrations.

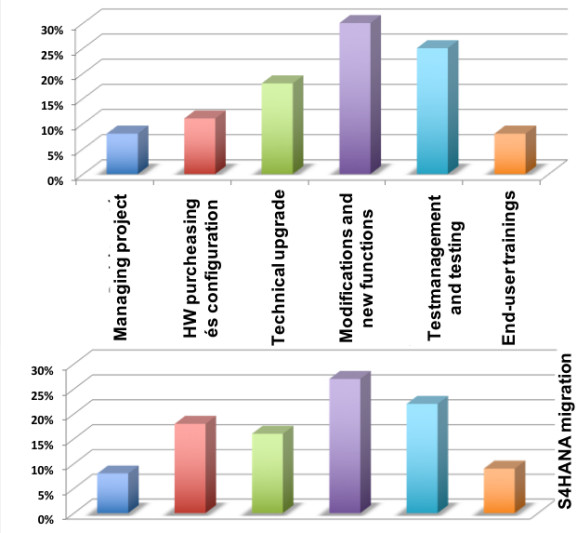

Figure 2 - Cost comparison (Upgrade and S4-migration)

When evaluating SAP implementation methodologies—namely ASAP and SAP Activate—it becomes evident that they guide clients toward minimizing standard modifications while advocating for adherence to established standards in order to achieve uniformity. From a software operational perspective, this approach suggests pathways toward simpler and more cost-effective sustainability measures thereby facilitating integration into the SAP cloud environment. Nonetheless, this trajectory may inadvertently stifle innovative development and creative thinking within organizations.

III. Version Control

After the implementation, it is imperative to engage in ongoing adjustments and enhancements, as the environment, business requirements, software, and internal processes undergo continual evolution. It has been demonstrated that a stable and functional environment can be established through the following measures:

- Establishing foundational guidelines and regulations that are adhered to consistently, supported by software tools.
- Implementing a centralized tracking system designed for documenting the environment, articulating requirements, managing projects and releases, as well as overseeing errors and extensions; this system must operate transparently in accordance with established protocols.
- Ensuring that the business possesses a comprehensive understanding of its operational processes.
- Granting ownership of both processes and interfaces to the business entities involved.
- Fostering professional acceptance alongside effective communication between business units and IT departments (including ERP development, configuration, technology, middleware, and infrastructure).
- Conducting collision assessments of modifications not only during their creation but also prior to their deployment (particularly pertinent in complex architectures and processes).
- Exercising development governance while supporting adherence to standards.
- Guaranteeing restorability at a granular level.

Though these points may initially appear flexible or ambiguous, upon closer examination they reveal substantial robustness. Their implementation simplifies operations while ensuring sustainability, compliance, and audit readiness. A critical component of this framework is the meticulous design of deployment processes that safeguard production environments without obstructing implementation efforts. To evaluate the impacts of modifications prior to execution, I have devised a straightforward routine accompanied by a treatment protocol. This procedure proves beneficial when transitioning between versions or during migration activities where both source and target environments are concurrently accessible. Prior to loading an SAP deployment unit—specifically a transport—I conduct comparative analysis on the modified object list referenced within it against both source and target environments. This approach clarifies necessary actions or adjustments required retrospectively. In instances where only the transport is available without access to the source environment, I have developed a compact portable environment capable of extracting content from the specified transport at the list level; this enables verification of objects slated for modification within the target system. Moreover, this procedure is advantageous in daily operations when decisions regarding third-party SAP transports necessitate evaluation prior to loading.

From a sustainability perspective, even within developmental systems it poses significant risk if transports compromise data integrity or overwrite customization or repository contents inadvertently. The proposed solution facilitates informed decision-making while necessitating careful consideration of deployment content beforehand. To effectively safeguard our systems against potential disruptions caused by loaded deployments, ensuring restorability emerges as one of the most vital needs articulated above; this capability permits restoration of elements altered by any given

deployment should an error occur. I will present two practical solutions aimed at achieving this goal—one has been implemented while foundations for another have been laid.

The first entails creating backups specifically for transport objects scheduled for loading; rather than performing standard database backups, a specialized transport can be generated at the SAP level capturing all objects associated with the deployment as snapshots before actual loading occurs. Consequently, this allows us to revert objects back to their pre-deployment states should issues arise post-loading. The second solution extends beyond mere snapshots by preserving object states separately within database structures; careful attention must be directed toward referenced table contents since SAP possesses its own version management system applicable to development objects which can facilitate reconciliation efforts between original settings and imported table contents. I have integrated such functionality into my prototype solution as well.

The outlined list addresses the management of conflicting deployments, necessitating early examination. It is imperative to prepare not only with appropriate tools but also through the establishment of a systematic environment and requisite authorizations. This preparation is particularly vital in template-based or expansive environments that undertake multiple tasks. The term "multiple tasks" implies that there are central configurations and developments essential for all stakeholders; however, due to certain delineations, additional specific configurations and developments may also be required. Examples include unique implementations operating on a centrally designed foundation that spans several countries and regions or the application of a template within diverse environments, contingent upon the template being updated. In the context of SAP, this discussion extends to distinct systems or even separate clients within a larger system. To address these complexities, I have formulated the following framework:

- Documentation of template rules
- Cataloging of object nomenclature (across various sectors, countries, regions, etc.)
- Establishment of reference roles concerning authority
- Management of discrepancies in central template codes: including dynamic codes, modularization units sharing identical signatures, delineation-dependent naming conventions (e.g., client, company code), and configurable module calls
- Nomenclature for transport objects as well
- Supplementary measures for SAP deployment: conducting template compliance tests prior to transport closure

With this comprehensive set of conditions and my prototype verification codes, the structural framework for the sustainable operation of template systems has been validated as effective.

To effectively safeguard objects and settings throughout the development and modification processes within agile methodologies, one encounters the concept of Continuous Integration/Continuous Deployment (CI/CD). The SAP Activate methodology incorporates this concept; however, it is limited to cloud-based services and does not extend to the ABAP environment. I have formulated a theoretical framework that aims to partially substitute and align with CI/CD expectations. It is crucial to acknowledge that the ABAP environment operates differently from conventional development environments due to its centralized state; any alteration results in a new version. In contrast, general environments facilitate the creation of parallel branches, allowing for multiple concurrent live versions which can later be integrated into a central track. For clarity, when considering an individual program, such functionality cannot be uniformly applied within the SAP context as previously noted. My proposed extension is procedural rather than software-based, although programs will ultimately play a role in comparison and merging tasks. The core elements of this solution include:

- All modifications are executed via fixed special inline comments.
- Code across different branches is managed independently by the system.
- CI/CD operations must be subject to control measures (authorization and inspection).
- Actions must be documented (identifying who performed what CI/CD action and when).
- During the merge process into the primary track, the central code must be locked.
- The control environment also logs activities using designated inline comments.

I have prepared detailed implementation guidance for this theoretical solution, which has facilitated practical application. Such an enhancement proves highly beneficial within any standard SAP ABAP environment, irrespective of version or implementation specifics.

IV. End-user Surfaces

From a sustainability perspective, the development of interfaces and integration has made significant strides, particularly concerning end-user interfaces, commonly referred to as User Interfaces (UIs). Two critical aspects emerge in this context that enhance usability and facilitate a more seamless experience for end users: the minimization of modifications and the autonomy of the user interface. My analysis encompassed the SAP system and various other Enterprise Resource Planning (ERP) solutions. It is imperative to first assess the options available within SAP's offerings. From the standpoint of SAPGUI, it is essential to provide a straightforward interface for end users from the outset. While SAP allows for personalization, operational efficiency may be compromised due to the variability in interface appearance across different users, thereby obscuring the core functionality for support personnel. In terms of web interfaces, since the inception of SAP Web Application Server (WAS), numerous solutions have been developed by SAP on its internal web server (Internet Communication Manager - ICM). Before WAS, web interfaces were accessible through Internet Transaction Server (ITS) solutions starting from version 3.17; these remain available as internal services today. The following techniques are offered by SAP:

- ITS:
    - SAPGUI for HTML (Standard SAPGUI presented as a web page)

  - Web Transactions (Standard SAP transactions displayed on a web surface with customization capabilities; transaction logic executed on the ABAP side)
  - Flow Logic (Execution based on RFC and BAPI; transaction logic processed on the ITS side)
  - WebRFC (Direct invocation of SAP RFC functions via the web)
  - Web Reporting (Direct access to SAP reports through the web)
- BSP (Business Server Pages; server-side scripting-based pages)
- WebDynpro (Model-View-Controller architecture-based web pages)
- SAPUI5 and Fiori (HTML5- and JavaScript library based development solution and implemented functions)

For developing authentic web interfaces, tools such as BSP—akin in logic to JSP or ASP used in Microsoft environments but utilizing ABAP as its scripting language—and WebDynpro—which provides a dynamically compiled interface around which standard environments and designs are generated by SAP—can be employed. In contrast, Microsoft Dynamics has established a role-tailored interface from its inception through its Role-tailored User Experience framework. For both software systems examined, interface creation is inherently integrated into their respective system environments. Through comparative analysis, I identified that a web interface is crucial for better-aligning user experiences with end-user requirements while effectively managing content display according to permissions and configurations. Empirical observations indicate that while SAP screens tend towards complexity, ordinary users who engage with only a limited set of functionalities find mobile app-like simplicity more than adequate. This suggests that my findings advocate for operating interfaces within an independent layer supported by services that furnish necessary data (Fig. 3).

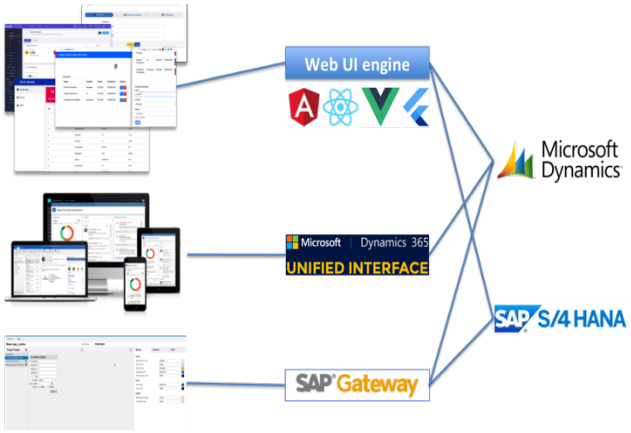

Figure 3 - Web-based multi-layer application independent engine

In contemporary SAP settings, it is advisable to utilize a dedicated ABAP system known as SAP NetWeaver Gateway functioning as a frontend server within this environment. The introduction of new interfaces termed SAPUI5—built upon HTML5 and JavaScript—is also recommended by SAP. Furthermore, standard offerings include Fiori Apps; however, it must be noted that these consist of two components: requisite Fiori foundations must exist within backend systems alongside additional elements required for frontend display. Additionally, NW Gateway permits the utilization of any data source—including MS Dynamics services or proprietary data—as potential sources underpinning these interfaces.

The design process necessitates collaboration with professional domains to accurately identify and integrate relevant data for display and management purposes. Consequently, I propose two pivotal sequential iterative steps:

1. Development of an interface plan outlining sketches, sample images, UI element placements, sequences, menus, functions etc.

2. Conducting tests involving laypersons drawn from target demographics—individuals lacking IT expertise yet required to interact with these systems—who will perform evaluations guided by their own logical frameworks which can yield valuable insights.

3. Consideration and incorporation of feedback [returning to point 1].

4. Implementation of the interface using test data—even without backend connectivity—utilizing simulated information.

5. UI testing conducted with laypersons focusing on logical structure issues pertaining to usability clarity while emphasizing salient elements.

6. Analysis of test results followed by modifications based on feedback leading into retesting [revisiting point 4].

The implementation of contemporary techniques is undoubtedly beneficial, as young individuals—comprising students and their parents engaged in public education—prefer interfaces that are straightforward and logical, requiring minimal interaction. Interfaces failing to meet these criteria tend to be disregarded. It is evident that user-friendliness aligns with current expectations, which is paramount for end users. I have tested the aforementioned simplified theory within the context of a project focused on subsidiary consolidation, and the results were notably positive; development proceeded more efficiently, as numerous components did not necessitate rewriting, allowing for the backend functionalities to be developed independently. Consequently, only the time required to ascertain the data retrieval functions invoked by the user interface needed consideration. This approach enhanced system sustainability, as it provided end users with precisely what they required without necessitating an understanding of backend operations.

V. Traceability, Dynamic Control

Sustainability is not only driven by regulatory frameworks and controlled developments but also necessitates the incorporation of traceability and auditability. These requirements, while often resulting in additional workload and potential increases in bureaucracy, are essential when maintained at a reasonable level. One of the most critical strategies to streamline this process is through the automation of data collection. Furthermore, clear rules and guidelines should govern the tasks of workers, developers, setup experts, and IT personnel to minimize confusion and enhance operational efficiency. To facilitate this, a central database is often required to dynamically extract and analyze relevant

data. The Information Technology Infrastructure Library (ITIL) framework also supports this approach, advocating for the use of a Configuration Management Database (CMDB) for centralization.

One of the greatest challenges in achieving sustainability lies in managing the frequency and scale of changes, as well as addressing potential attempts to conceal or circumvent them. Change, however, is a fundamental aspect of development. Without change, progress becomes impossible. To address this, I have categorized changes and compared their effects and corresponding tasks across different categories. I have prioritized major changes based on their underlying motivations, which may include the introduction of a new system, the replacement or continuation of an existing one, or technical, functional, or strategic modifications. For example, changes may be motivated by the cessation of maintenance, the correction or expansion of functionalities, or the introduction of a new module or solution. Strategic modifications can be further broken down into categories such as system upgrades, Unicode conversions, operating system/database migrations, S/4HANA conversions, or transitions to SAP Private Cloud (RISE) or Public Cloud (Grow), which are often driven by license changes. These large-scale changes must be addressed separately, as they can impact end-users, operations, and the broader organizational structure.

- Upgrades: System upgrades primarily affect operations during the project phase, and key users typically experience shifts in responsibilities. For most end users, these changes are minor and barely noticeable. The infrastructure and SAP technical teams, however, are tasked with hardware resource expansion, integration, and the management of parallel systems during the upgrade process. Additionally, user education may be necessary if, for example, Fiori interfaces are introduced in the new version.
- Unicode Conversion: This process mainly places significant demands on consulting teams, but the infrastructure and SAP technical teams also play a crucial role, particularly due to increased hardware requirements. After the project concludes, these teams can return to their standard operations. Key users may need temporary knowledge of text conversion processes during the project, though this task is limited to the project timeline.
- Operating System/Database Migration (OS/DB Migration): Similar to Unicode conversion, OS/DB migration primarily impacts technology teams. However, migrating the operating system can involve more extensive tasks that persist beyond the project's completion. For example, switching from Windows to Linux, Unix to Windows, or from AS/400 systems requires changes in file-sharing management and may necessitate ABAP-level system adjustments or even program changes. These changes lead to permanent operational shifts, including potential transfers of SAP system management to different teams. Processor architecture changes, such as a transition from x86_64 (Intel, AMD) to IBM PowerPC, represent a special case that requires learning, operational procedure adjustments, and sometimes new team formations.
- S/4HANA Conversion: This process combines upgrade tasks with OS/DB migration while introducing application-level conversion procedures. In this case, Fiori interfaces become mandatory for many functions, and SAPGUI interfaces undergo changes, significantly impacting end users. As a result, end-user training becomes essential. For the technical teams, this conversion merges the responsibilities associated with both system upgrades and OS/DB migration. Additionally, in many instances, database management may transfer to SAP's technical team, as HANA is an SAP product. This transfer necessitates training for technical staff, as SAP's internal administrative interfaces differ from those in previous versions.
- License Modification from On-Premise to On-Cloud: It is important to recognize that modifying a license does not equate to transitioning SAP systems from on-premise to the cloud, as the operational environment dictates the mode of operation. Under an on-premise license, the customer operates the SAP system in their data center, a hosted environment, or via a public cloud provider such as AWS, Google, or Azure. In contrast, an on-cloud license transfers part of SAP's technological (Basis) operations and infrastructure management to SAP, which the customer purchases as a service. This shift impacts the financial structure, infrastructure requirements, and operational processes while reducing the need for SAP Basis activities. Although interface management (e.g., middleware tools) remains the customer's responsibility, SAP assumes control over database and host management. When using the on-cloud license, it is essential to differentiate between SAP's public and private cloud services. As indicated by the SAP Activate methodology, the public cloud offers a more standardized environment, wherein operations such as patching are centrally managed and scheduled without customer input. While this simplifies operations for the service provider, it necessitates additional testing and planning on the customer’s side. The private cloud, on the other hand, offers a more customized environment with fewer mandatory patching requirements and more services managed by SAP. Organizational changes under the cloud model include the addition of a service request step, which replaces certain implementation tasks. However, a SAP technology specialist is still required to facilitate communication between business and IT, translate business needs into SAP Service Requests (SR), and coordinate schedules between SAP and the business. This role demands comprehensive knowledge of the system environment, processes, and technologies, extending beyond general SAP Basis expertise.

In summary, managing large-scale changes in IT systems, particularly in the context of SAP, requires a structured approach to change categorization, impact assessment, and role-based task allocation. By prioritizing automation and centralizing data management, organizations can better navigate the complexities of sustainability, ensuring efficient operations while minimizing disruptions caused by necessary technological advancements. The smaller changes in the software can be easily handled by using my *variation buffer* theory mentioned before.

VI. Conclustion

This article presents a comprehensive examination of various domains, emphasizing that the sustainability of an environment extends beyond mere operational aspects to encompass a multitude of pertinent topics. I propose frameworks and structures aimed at enhancing sustainability within systems, landscapes, or expansive environments. The following key areas are addressed:

- alternative methodologies that diverge from conventional requirements yet demonstrate greater efficiency,
- agility in the implementation and development processes of Enterprise Resource Planning (ERP) systems, particularly through driven development methods,
- the establishment of interfaces that facilitate connections across multiple layers involving diverse professional stakeholders,
- critical considerations during upgrade, migration, or conversion projects,
- the formulation of a version control framework and variation buffer,
- the enablement of Continuous Integration/Continuous Deployment (CI/CD),
- the definition of web surface requirements along with design principles that eliminate modifications and subsystem dependencies.

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The impact of automation of manufacturing processes on employees in the context of Industry 4.0: an analysis of social and psychological factors

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Abstract **This article presents a case study found in a Romanian company, regarding the automation of a manufacturing process by introducing intelligent technologies having as determining role the improvement of the technological flow by reducing the time related to the launch of work orders in production, automation of repetitive tasks, increasing the accuracy of execution of work phases, real-time monitoring of the entire path of raw material. At the same time, by implementing smart technologies, part of industry 4.0, the company described in the case study brings a number of changes in the way of working related to the production area by reorganizing human resources: retraining and redeployment of employees, efficient use of manpower by planning and standardization of the teams used, all of which have a major impact on employees. The main purpose of this case study is to analyze the impact on the human psychic and social from which it is possible to realize that an automation process afferent to an area of activity synchronized and interrelated with the others, as component elements of a whole (the company's activity), will have a positive impact because the workforce can be redistributed in an efficient way to other sectors, certain resources can be absorbed by the production sector, for a maximization of productivity, which will ensure a number of benefits for employees.**

Keywords—SAP, ERP, Industry 4.0, automation, RPA, production management, process

I. INTRODUCTION

Over the years, the integration of intelligent technologies (IT) in automotive related companies has brought a number of benefits, with AI (Artificial Intelligence), RPA (Robotic Process Automation) or iRPA (Intelligent Process Automation) based IT solutions bringing added value in terms of the possibility to model the manufacturing processes existing in this area of activity. In this scientific article the authors have carried out a research based on the interventionist method, participating in the modeling of an economic process used in the release of production orders for spare parts, based on a production plan realized by the logistics department of a Romanian factory, part of a worldwide group dealing with the production of components used for various car brands.

The aim of the company's management was to optimize workflows, to improve the usability of existing production processes and to integrate the above-mentioned IT into existing workflows. The way employees work has also seen a number of improvements, repetitive things have been replaced, leading to increased speed and accuracy in manufacturing processes.

The other aspect solved by the introduction of IT was to reduce downtime by monitoring the condition of equipment in real time to prevent unexpected breakdowns. At the same time, the optimization of production flows by using AI algorithms to dynamically adjust assembly lines according to demand and capacity also had an impact on the production itself, so that the distribution of workloads was done automatically, productivity increased, and by this way the current challenges in the automotive industry, such as the demand for high quality production, cost efficiency and environmental compliance, were met. Not to be overlooked was the need to adopt IT to remain competitive in an increasingly technologized and demanding market.

Safety and security aspects in the workplace have been significantly improved through the introduction and use of sensors and AI technology to identify and reduce the risk of accidents, thus ensuring a significant improvement in employee safety. Aspects such as the detection and prevention of health-related risks have also been taken into account, with smart technologies providing company management with monitoring of working conditions such as temperature or air quality, thereby providing employees with a healthy and safe working environment.

Regarding the central role of the adoption and adaptation of smart technologies in the automotive industry, together with the integration of Industry 4.0 components, they have led to the modernization of production in this area of activity. Moreover, the implementation of key Industry 4.0 concepts such as Cloud Computing, IoT, Big Data and Cybersecurity have brought about a significant transformation in the way automotive manufacturing is managed [1].

These technologies make it possible to optimize production processes and improve operational efficiency, ensuring a better adaptation to the needs of a competitive market in this field. One aspect that the authors of this article considered and used as research was how the automation of economic and production processes, as well as the integration of AI for streamlining operations, had an expected effect on the users in the analyzed company, those who have SAP as their integrated information system. Thus, by utilizing

artificial intelligence (AI) in production processes, a continuous improvement of workflows will be achieved.

The implementation of SAP systems within the framework of Industry 4.0 has both positive and negative implications on the social and psychological factors affecting employees. On the one hand, SAP systems demand a continuous adaptation to new technologies, which can lead to technostress, job insecurity, and cognitive overload. Employees may experience social isolation as automated processes reduce human interaction, and the pressure to maintain or acquire new skills can lead to anxiety and burnout.

II. Social and Psychological Factors Associated with Production Order Release Automation

A. Organizational Context

The automotive industry is in an era of unprecedented digital transformation. ERP systems, like SAP, can automate workflows and are the backbone of many automotive factories by optimizing activities in the following areas of the business: logistic services, human resource management, financial management, procurement management and production planning. While the technological impact is plain to see - processes are becoming faster, more efficient and costs are reduced - what happens at the human level is often overlooked. Behind these improvements is an important challenge: what happens to employees working in an increasingly digitized industry? The transformation of the working methods and used tools at a very fast pace impact their behaviors and perceptions: the possibility of losing their job, the rigidity of employees to adopt new ways of working, the fear of career stagnation, etc.

B. An analysis of social and psychological factors

Production processes can be automatized through the use of SAP systems and other smart technologies, that significantly improve the efficiency of production order release by reducing order release time, increasing accuracy, improving activity monitoring, etc.

One of the main social factors associated with the implementation of automation in industries is the perception of insecurity in the workplace. The perception of these improvements and automation of management systems is that it will reduce the need for human labor, which can negatively affect the involvement of employees in the business as usual activity of the company [2]. The implementation of SAP automation can profoundly affect the workforce, triggering responses ranging from enthusiasm and empowerment to fear and resistance.

These improvements require a shift from manual to cognitive tasks: with SAP automation handling routine tasks, employees may feel a shift towards more intellectual or decision-making roles. People quickly develop a strong fear of being replaced with a system, given the tendency of technology to take over repetitive or manual tasks [3]. This shift may lead to job development in the direction of automation or, on the other hand, a sense of increased pressure. If automation takes over many tasks, employees may worry about their role becoming redundant. Will this lead to improved working conditions or to layoffs? Employees may feel like they are losing control over their work, because of dictating tasks and schedules based on algorithms. Uncertainty related to the job, after automation of processes, can result in lower engagement from the employees or a desire to leave the company.

For SAP-based automation of production processes, advanced technical skills are required, implying an increased need for qualification, training and continuous upskilling of the workforce. Studies show that employees who receive specifically tailored training programs are more open to accept and sustain technological change [4]. Employees may question the accuracy and reliability of automated systems, leading to a sense of hesitation when transitioning. Unfortunately, in a lot of companies that are using ERP systems, not all employees are correctly trained from the beginning of the transformation, so that the fear of replacement disappears, and many employees become stressed and refuse to engage with change, experiencing technology anxiety and feelings of irrelevance and powerlessness, which reduces active involvement in production processes. Businesses should invest in developing employees' technological and digital skills to help them transition with ease and reduce their natural resistance to change.

Automation has a double impact on employee motivation. On one hand, by eliminating repetitive tasks, SAP can increase satisfaction as employees can focus on more creative and strategic activities. On the other hand, if employees perceive automation as a threat to their professional value, this can lead to decreased motivation and alienation from the work. Perceptions of one's own competence play a key role in how employees respond to automation. According to self-determination theory, individuals are motivated when they feel that they have control over their work environment [5].

C. The role of leadership and importance of communication with the employees

Process automation can significantly alter leadership structures and organizational hierarchies. Employees in IT and financial departments, and those with strong digital skills, become critical to successful implementation, which can lead to imbalances in the distribution of influence within the team. In the absence of well-planned change management strategies, this imbalance can lead to conflict and decreased collaboration between departments. How management communicates the benefits of SAP automation is crucial. Lack of transparency can lead to misconceptions about the intent behind the automation, feeds anxiety [6]. In the automotive industry, those with advanced digital skills are becoming increasingly important. This shift can affect team dynamics, especially in productive teams, as employees who lack these skills can feel they lose momentum and motivation. It is very important that the management balances this by providing support for the development of technical skills [7].

Employees are trained to trust the system’s accuracy in executing tasks such as stock checking and production order releases. If the system fails or produces errors, it can disrupt the entire production process, affecting the reliance on the system. Being more and more dependent on technology may lead to anxiety about system failures, making either employees feel helpless if things go wrong, or understand the system well might feel a greater sense of control and competence [8].

The active involvement of employees in the planning and implementation phases is essential to ensure the success of the

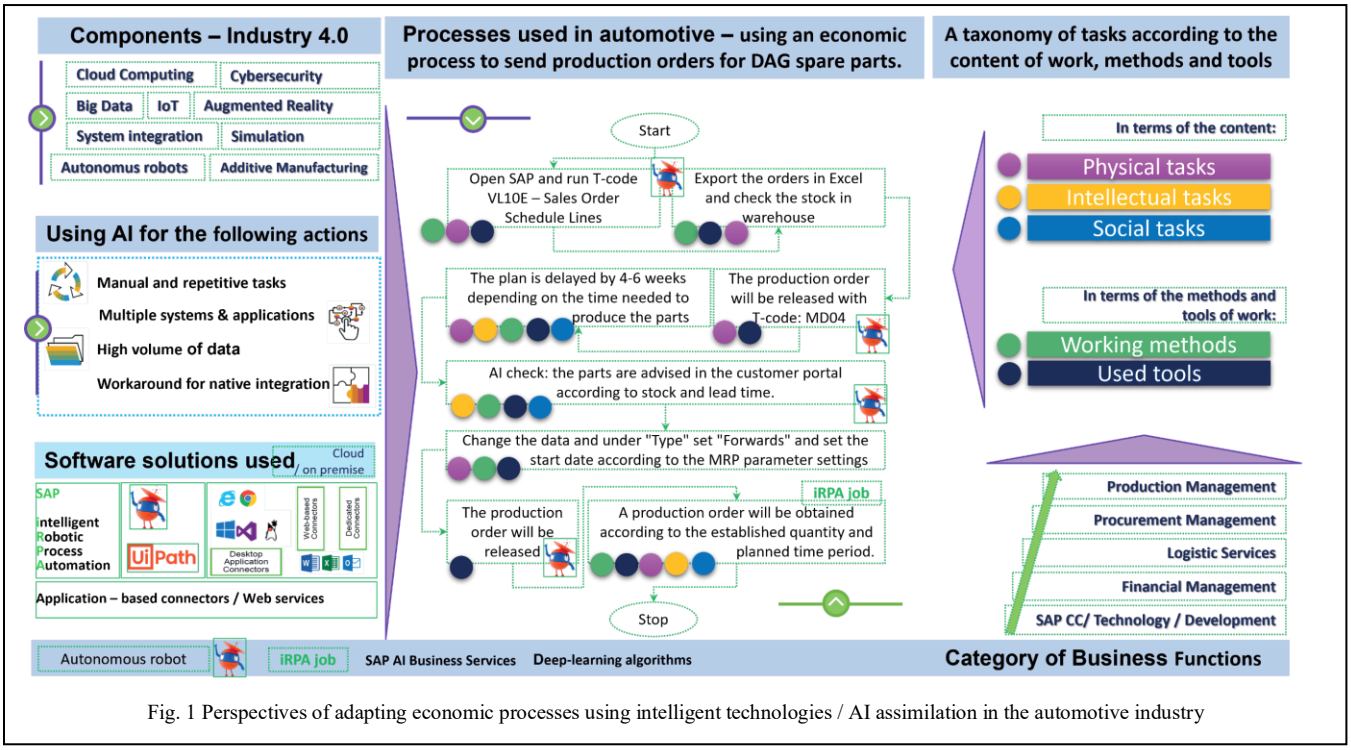

Fig. 1 Perspectives of adapting economic processes using intelligent technologies / AI assimilation in the automotive industry

technology transition. Including them in decision-making processes related to SAP implementation helps to create a sense of control and ownership over change. Organizations that foster a participative management style tend to reduce the level of resistance to change, increasing employee commitment and satisfaction [9]. If employees are consulted and feel part of the decision-making process - for example, on how SAP will be implemented in production - they will be much more willing to embrace and support these changes. Automotive companies that engage teams in this way manage to implement new technologies more easily and keep morale high [10].

III. The Study Case

In the manufacturing work area, the adoption of smart technologies with SAP has brought numerous benefits and radically transformed the way operations were and are managed. It is obvious that management's decision to adopt smart technologies was made with several arguments in mind, some of which are specified by the authors of this paper in the body of this paper. It was based on the idea of automating repetitive and routine tasks, so that intelligent technologies, such as industrial robots and RPA (Robotic Process Automation), were intended to take over repetitive tasks, thus allowing employees to focus on activities that have an added value for them and for the company [11]. Another aspect taken into account was workflow optimization, here SAP, combined with artificial intelligence (AI) and machine learning algorithms, could automatically adjust production processes according to demand and capacity, reducing downtime. Figure 1 depicts a production process for the production of spare parts for a well-known manufacturer of electrical cars.

The flow describing production orders for spare parts demonstrates how the automobile industry has persistently worked to increase the efficiency of production, by incorporating intelligent technologies. Key processes in the production management lifecycle are automated using SAP, AI-driven algorithms, and machine learning, as shown in the schematic in Figure 1. To manage the sales orders, the procedure starts by executing the transaction code "VL10E" in SAP. Then the orders are exported to Microsoft Excel, so that they can be compared to the stock in the warehouse and to do an initial assessment of whether the parts are easily available or require production can be made. A planning phase is entered if production is required and the stock is not enough. Depending on how long it takes to make the parts, the production timeline may reach four to six weeks.

The SAP system's MRP (Material Requirements Planning) parameters are used to integrate many checks, including lead time, client orders, and stock availability, in order to account for these delays. The system automatically notifies clients about part availability via the site. The manufacturing orders are notably aligned with predetermined characteristics, such as quantity and lead time, by the execution of a Robotic Process Automation (RPA) job.

This automation makes sure that the intelligent system manages operations that are normally done by hand, including changing start dates or recalculating production numbers. The automatic release of production orders marks the end of this workflow, guaranteeing that everything proceeds without a hitch from order reception to the commencement of production with minimal human involvement. Modifying production in response data inputs that happen in real time, SAP's AI and machine learning implementation helps reduce working time and maximize resource utilization in this scenario. In addition to increasing manufacturing efficiency, this enables businesses to better satisfy shifting consumer wants. It is critical to evaluate the larger consequences of implementing intelligent technologies such as SAP, AI, and RPA on the workforce, in order to ensure employees retention and wellbeing. As companies automate regular operations, individuals' roles and responsibilities unavoidably change. While automation lowers manual labor and improves operational efficiency, it also creates new problems and opportunities for employees. Employees can feel more at ease from repeated duties, allowing them to focus on more

important activities like decision-making, innovation, and problem-solving.

This increases job satisfaction and also personal growth. But this shift from the usual day-to-day tasks to something newer and that requires creativity, may raise concerns about job security, the necessity for reskilling, and the worry of adjusting to new technologies. These social and psychological aspects must be delicately handled to ensure a smooth transition to a more automated production environment, with less change resistance from employees. Researching and understanding the human view on technology change is important, and so is the technical execution of what the company wants to automate, because this has a direct impact on employee well-being, productivity, and organizational culture.

CONCLUSIONS

AI-driven technologies are increasingly being used and are being applied in various actions such as production planning, inventory management and operational performance analysis. This helps reduce human error and optimize decisions based on a range of data provided and collected in real time. As for the importance of using autonomous robots or even more so iRPA in the production environment is another aspect that the authors of this scientific paper researched during their participation in modeling the discussed economic process, so one thing is for sure that advanced technologies such as autonomous robots and iRPA (intelligent Robotic Process Automation) are meant to automate repetitive and dangerous tasks, in this way of working reducing operational costs and improving workplace safety.

The integration of these solutions with SAP systems and other IT platforms contributes to better visibility and control over all production processes. Another topic discussed by the authors in this article was the classification and optimization of work tasks to achieve efficient production.

In this respect, they concluded that the taxonomy of work tasks according to work content (physical, intellectual and social tasks), as well as the work methods used, highlight the need for a structured approach to process optimization. The correct choice of work methods and tools is essential to achieve maximum efficiency and to improve the quality of the end products. Another topic discussed with the analyzed company was the possibility of using software adapted to the ecosystem used for smart manufacturing, in this sense it can be stated that IT platforms such as SAP, existing Cloud solutions as well as RPA or iRPA applications are integrated, this aspect ensures process continuity and efficient management of the production cycle.

This way of working as well as the use of these IT solutions helps to automate decision-making processes, to monitor and control the condition of equipment as well as to manage financial and logistical resources. As a general conclusion it can be mentioned that the integration of smart technologies in the business environment, in production in particular, brings benefits in various processes found in the business environment such as production management, logistics, purchasing and financial accounting. The use of advanced IT systems allows the coordination of activities in an efficient way between different departments, thus improving the flow of information and the necessary collaboration. As a general conclusion, the adoption of smart technologies in automotive manufacturing processes not only optimizes operations and reduces costs, but also paves the way for greater flexibility and adaptability to changes in a fast-moving competitive market. Combining as many Industry 4.0 components as possible with modern software solutions, such as SAP, RPA and iRPA, ensures intelligent and connected manufacturing, ready to meet the complex and evolving requirements of the automotive industry, locally and globally.

On the other hand, for those who successfully adapt, SAP systems can foster empowerment, enhance decision-making abilities, and improve job satisfaction through access to real-time data and better resource management. Additionally, organizations that provide adequate training and support can help employees leverage these tools for personal and professional growth, ultimately leading to more engaged and motivated staff.

Therefore, to mitigate the negative psychological impacts, companies must focus on comprehensive change management strategies, continuous training programs, and fostering a supportive work environment that promotes adaptability and resilience in the face of technological advancements.

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ERP Adoption and Data Maturity in Hungarian SMEs: an Industral Analysis

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***Abstract*— The main objective of the following projects is to assess the current state of digital transformation (based on their data maturity assessment) of Hungarian SMEs and midcaps, with a focusing on their readiness to adopt advanced AI and data technologies. This paper presents the results from two major initiatives—GINOP-3.2.8-20-2020-00001, entitled "AI Innovation and Competence Centre: Building Data Management Capacities for Hungarian SMEs to Promote AI Applications," (GINOP 3.2.8) and Data-EDIH which is part of the European Digital Innovation Hub network. The GINOP 3.2.8 project examined the adoption of Enterprise Resource Planning (ERP) systems among other dimensions of data and AI maturity.**

Meanwhile, the ongoing Data-EDIH project focuses on identifying the specific digitalization issues, including those related to ERP systems and providing solutions, trainings, consultations to help overcome these barriers. The results underscore the importance of supporting digital maturity and ERP integration to enhance the competitiveness of Hungarian SMEs in the AI and data-driven economy.

Keywords—Data Maturity, ERP system adoption

I. INTRODUCTION

The digital transformation of small and medium-sized enterprises (SMEs) and midcaps is critical for business success in today's data-driven economy. In Hungary, two key projects — GINOP-3.2.8-20-2020-00001 (2021-2023), titled "AI Innovation and Competence Center: Building Data Management Capacities for Hungarian SMEs to Promote AI Applications," and Data-EDIH (2022-2025, European Digital Innovation Hub, www.edihnetwork.eu) — were launched to assess and support the digital maturity of Hungarian SMEs, focusing on their ability to adopt advanced AI and data technologies.

One of the objectives of the GINOP 3.2.8 project was to understand the level and dimensions of adoption of ERP systems in different sectors. The findings revealed significant differences in ERP usage and identified challenges, particularly related to the partial integration of these systems, which limit the full potential of digital transformation. In parallel, the Data-EDIH project seeks to address the practical challenges SMEs face in using ERP systems, providing insights into how to overcome these barriers and encourage wider technology adoption in their operative tasks. This paper examines the findings of both projects.

In GINOP 3.2.8 we assessed the digital and data maturity of 252 Hungarian SMEs in the manufacturing, trade and services sectors (see Figure 1.) and offered trainings and Proof-of-Concept and Proof-ot-Technology services.

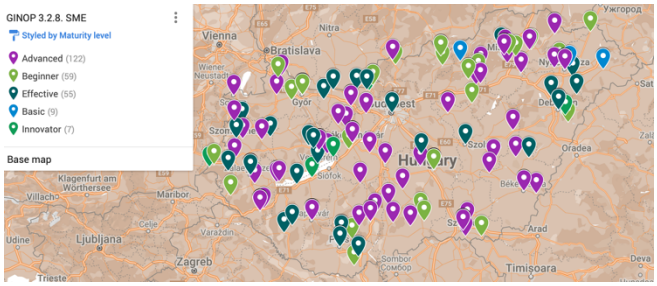

Fig. 1. GINOP 3.2.8 clients by maturity level

The assessment process and service for the Data-EDIH project is ongoing, with assessments completed for 119 companies to date (although we already offered our services, mainly workshops almost 200 organizations inc. public organizations). These initiatives aim to support the digital transformation of these companies through consultancy and training, with a focus on improving their operational efficiency and technology adoption. An essential component of this development is the use of an Enterprise Resource Planning (ERP) system or plans to implement one. Although we did not ask for the name of the ERP system in the data maturity assessment, it often comes up in consultations, although no specific statistics are kept on this information. This article examines the relationship between the data maturity of Hungarian SMEs and the implementation of ERP systems.

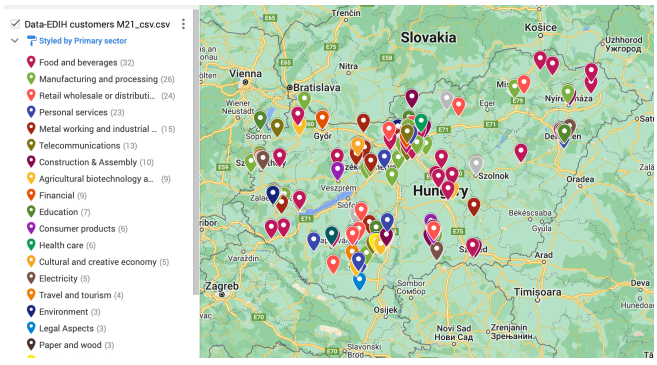

Fig. 2. Data-EDIH clients by sector

II. DIGITAL AND DATA MATURITY

Digital and Data Maturity assessment is essential not only for benchmarking an organization's current digital capabilities but also for tracking it's improvements over time, by providing a clear roadmap for their digital transformation. Digital maturity evaluations help businesses understand their current level of digitalization, pinpoint gaps in their technological infrastructure, and provide insights into areas where they need to improve. There are several maturity assessment tools and services available, some self-assessment,

others with the help of a consultant or a hybrid approach to provide the best results [1], [2], [3], [4], [6].

As part of the GINOP 3.2.8 project, a hybrid assessment questionnaire was designed along the following dimensions: size, sector, experience in the field of artificial intelligence solutions, management and staff commitment to digitalisation, digital skills and tools, data and AI development plans, management decision support tools, ERP system adaptation, data collection, storage and security tools, etc.

The Data-EDIH project uses the Digitial Maturity Assessment tool of the EDIH network [9]. The Digital Maturity Assessment (DMA) Tool, developed as part of the EDIH framework, is designed to evaluate and monitor the digital maturity of SMEs and mid-sized enterprises before and after receiving support. This tool assesses critical dimensions such as business strategy, technology adoption, digital readiness, and the human-centric approach to digitalization.

Digital maturity covers several key dimensions, including data management, IT infrastructure, integrating advanced technologies and organisational culture. By measuring maturity in these areas, organisations can gain a holistic view of their digital strengths and weaknesses, paving the way for more informed investment decisions in technology and workforce development.

III. Results of the Assessments

Although both projects target similar business sectors, there is less than 15% overlap between the companies involved in each project, giving us a broader view of the challenges and opportunities in the digital transformation of SMEs across the country.

The main results of the assessments are the followings:

Organisations achieve their results by maintaining and increasing their competitiveness through continuous improvement. In order to operate effectively and successfully, companies need to align their core activities, i.e. value-creating processes, technology and culture, with their organisational structure and the necessary support processes, while continuously reducing processes that do not generate redundant benefits. Predicting the evolution of external and internal key factors will help companies to achieve different organisational goals. A company's value-creating processes are, in fact, the set of processes and activities that support the achievement of the objectives for which a company was created.

It is particularly interesting to look at this parameter category where 44.1% of all enterprises (innovators + efficient) were in the high development segment. A further 31.3% were in the advanced segment, while almost ¼ of the enterprises were in the basic or entry segment. The digital index of value-added processes is highest in the manufacturing segment when the top 3 classifications are taken into account, with the share of innovators in this area being the highest in the services segment at 46.4%!

The GINOP 3.2.8 project surveyed 252 companies outside of Budapest and Pest County, focused largely on practical aspects of digital maturity such as ERP system integration, automation of business processes, and overall IT infrastructure. In this project, the manufacturing sector showed the highest maturity levels, especially in process automation and IT integration, with companies consistently scoring in the Advanced and Innovator categories. Meanwhile, sectors like trade and services lagged behind, particularly in areas such as strategy and customer service automation, where scores ranged from Beginner to Advanced.

Typical maturity categories for SMEs			
	Manufacturing	Trade	Service
Company culture	Effective (4)	Effective (4)	Effective (4)
Strategy	Advanced (3)	Beginner (2)	Basic (1)
Automation of service processes	Innovator (5)	Innovator (5)	Innovator (5)
IT	Advanced (3)	Advanced (3)	Advanced (3)
Customer service, customer experience	Effective (4)	Effective (4)	Advanced (3)
Automation of value-creating processes	Advanced (3)	Beginner (2)	Innovator (5)

Fig. 3. Maturity categories for SMEs (GINOP 3.2.8)

In comparison, the ongoing Data-EDIH project, which has so far assessed 119 companies, takes a more holistic view of digital transformation, focusing on broader themes such as digital strategy, human-centric digitalisation, and automation intelligence. The average digital maturity score across these companies is 31.55%, indicating that most are still in the early stages of their digital journeys. Notably, the Human-Centric Digitalisation category leads with a score of 40.66%, suggesting that companies are making progress in integrating digital tools with a focus on people—whether employees or customers. However, Automation Intelligence lags significantly, with only 12.74%, highlighting a major gap in the adoption of AI and advanced automation tools.

In the Data-EDIH project:

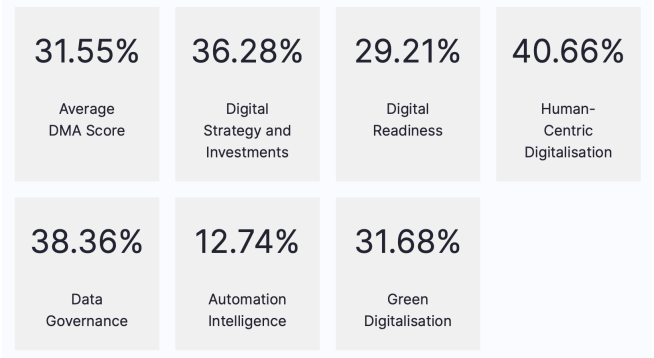

Fig. 4. Maturity categories for SMEs (Data-EDIH)

A. AI and Data Development plans

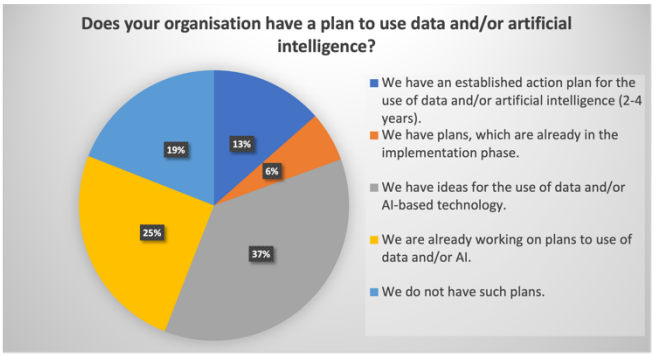

Fig. 5. AI and Data development plans (GINOP 3.2.8)

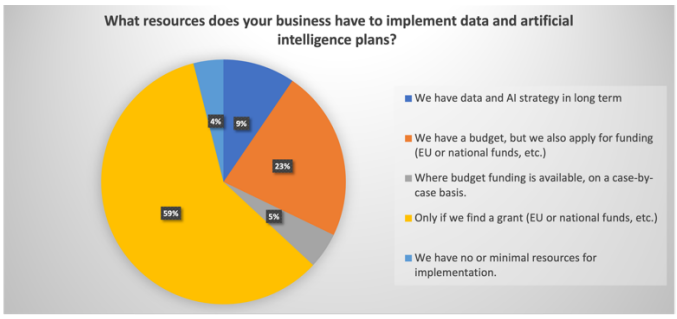

Fig. 6. Resources for AI and Data development (GINOP 3.2.8)

The survey shows that there is a low awareness of data utilisation and/or AI project plans. Nearly 60% of firms are only able to or plan to develop if they apply for a grant.

B. *Using Management Information System / Decision Support Services*

The survey asked SMEs how management receives information about business processes. The results show varying levels of information automation and manual processes, reflecting the digital maturity of these organisations across different sectors.

According to the findings, 21.4% of companies use fully automated, continuously updated, real-time reports. These reports are accessible on any device, providing managers with a constant view of the company's operations. This indicates a high level of digital integration where data-driven decision making is well supported.

For 36.1% of companies, regular digital reports that are automatically updated are the primary source of management information. These reports integrate existing data, suggesting that while these companies may not be fully automated, they rely on digital tools to a significant extent.

A more compartmentalised approach is seen in 15.5% of companies, where such digital reporting only exists at a departmental or divisional level. This means that while certain parts of the organisation benefit from digital insights, others still rely on less integrated or manual processes.

The survey also found that 25.8% of organisations rely on manual data collection and reporting. This suggests that there are significant inefficiencies in the way these companies handle their operational data, with senior management relying on manually generated reports to make decisions. Notably, 1.2% of companies reported that all key information is managed by a single individual, often the owner or senior manager, who personally oversees and understands the business processes without the aid of formalised systems.

The sector breakdown provides further insight into the state of digital transformation. The manufacturing sector appears to be the most advanced, with 76.8% of firms using automated or regularly updated digital reporting. This suggests that manufacturing companies are likely to benefit from the automated data flows generated by production processes and specialised production systems, such as manufacturing execution systems (MES) or methods such as kanban and just-in-time (JIT) production. The survey didn't look specifically at how these systems contribute to data generation, but it is reasonable to assume that automation in manufacturing facilitates higher levels of digital integration.

In contrast, the services sector lags behind, with 33.9% of companies still using manual reporting. The commercial sector fares slightly better, with 23.9% of companies relying on manual processes, while none of the manufacturing companies reported using manual data collection for management decision-making.

C. *ERP adoption*

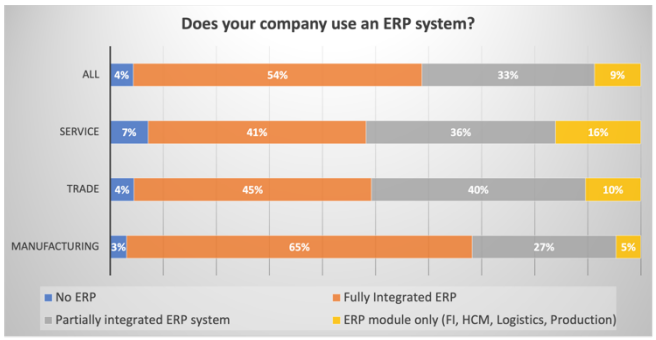

Fig. 7. ERP implementation (GINOP 3.2.8)

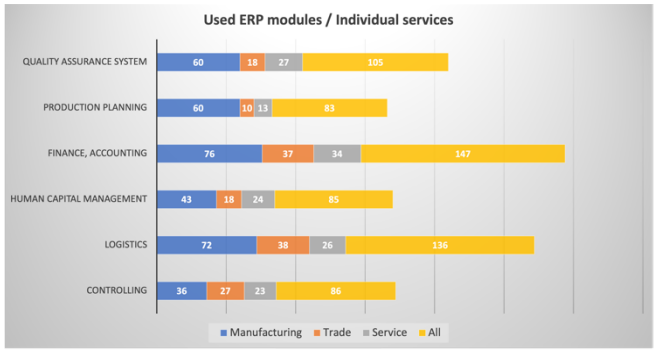

Fig. 8. ERP modules (GINOP 3.2.8)

More than half of the companies have an integrated ERP system (54%) and 33.7% have partially integrated modules supporting each functional area. Without integration, 7.5% of companies use business software applications. No ERP application at all is used by 4.4% of all companies.

Of the modules or solutions individually identified as not integrated, respondents identified finance, accounting; human resources; applications, logistics (including purchasing) and inventory management; controlling and decision support; applications supporting production planning and/or execution. Fully or partially integrated systems are in use by 93.6% of manufacturers, with over 10% in the trade segment (83.6%) and over 10% in the services segment (78.6%).

D. *ERP-related Business Problems*

Within the Data-EDIH project, assessing digital maturity goes beyond standard questionnaires. The process includes an in-depth consultancy interview, where the client's business challenges are analyzed as well. Based on the consultation and the DMA survey, a service offer is made to the client.

During these consultations, a number of common business challenges emerged, particularly in relation to ERP systems and data management strategies. For example, several clients required assistance in improving the level of integration of their ERP systems, in particular by establishing robust data management strategies and data workflows. This reflects the

growing need for companies to optimise their internal processes and use data more effectively for decision making.

Other common themes included

- Integrate billing and restaurant software for smoother operations and data flow, highlighting the importance of software interoperability.
- ERP and fleet management systems integration.
- Custom development of integrated ERP and management information systems to support operational processes.
- Optimising production planning, which many manufacturing companies have identified as a key area for improvement.
- Adopting and mastering the use of AI-based controlling tools to improve financial oversight.

This highlights the importance of ERP systems and data management as interrelated areas. Data management is also for supporting business and strategic decisions related to the operation of the company. ERP systems help by integrating processes across departments, allowing data to flow and be used more effectively.

Efficient data management should directly support decision making, optimise processes and improve business performance. ERP systems are not only for register and track the business transactions but also to improve the ability of an organization to make data-driven decisions that lead to better business results. Managing ERP and data together is essential to ensure operational efficiency and strategic success.

IV. Research objectives on Data and ERP Maturity Model

On the result of the projects my research objective is to combine a data and an ERP maturity models to help organizations create a comprehensive framework that not only focuses on process optimization and technology adoption through ERP but also on how well the organization can manage, govern, and leverage its data for decision-making and performance improvements.

My main assumptions so far are that only the hybrid maturity assessment will deliver results, and that it should be part of a development process that includes consulting. Neither data nor AI maturity alone is enough, but neither is ERP, they need to be managed together in one model. As the ERP maturity models are focusing on business processes and adoption of business information systems, related technologies, on the other hand data and AI maturity models are focusing.

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