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A Realistic and Practical Guide for Creating Intelligent Integrated Solutions in Higher Education Using Enterprise Architecture

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Abstract: Enterprise architecture (EA) plays a crucial role in organizations by providing a clear strategy for digital transformation and seamless information flow across boundaries. It is a tool for achieving current and future objectives effectively. By providing a comprehensive view, EA helps organizations build suitable and sustainable software solutions while avoiding complex challenges caused by unmanageable information flow blockages. Moreover, EA provides a standard framework for implementing enterprise resource planning (ERP) systems. Although EA and ERP systems have different concepts, they possess complementary characteristics that support decision-makers in the ERP selection process, which can be quite risky due to cost feasibility, time consumption, and team effort. This study proposes using the EA concept as a reference module for selecting the most suitable integrated solution for the higher education sector. The aim is to provide high-impact criteria for choosing the most appropriate ERP system as a core solution. Additionally, EA supports other related solutions integrated with the ERP system under the EA umbrella to run a fully automated smart entity. To determine the most suitable ERP solution for higher education entities in the study country, a set of critical criteria for ERP selection as a core solution in the education sector is generated through brainstorming, which is based on an EA reference module specifically designed for higher education entities that seek to operate smartly. A comparison technique is employed to evaluate the highlighted criteria, including a case study for ABC University. The study's results reveal that fully integrated and sustainable solutions can be envisioned for higher education entities, which can support the digital transformation of the higher education sector based on a smart EA reference module along with a set of critical main ERP selection criteria. This can mitigate the risk associated with ERP selection as a core solution and support decision-makers in selecting the most suitable ERP package for educational entities.

Keywords: enterprise resource planning (ERP); enterprise architecture (EA); educational sector; smart university reference architecture (SURA); The Open Group Architecture Framework (TOGAF)

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1. Introduction

Digital transformation has become mandatory for most entities to run their business cycle in a smooth and controlled way. Different entities depend on each other in running operations and exchanging information flows. Additionally, business automation becomes urgent for keeping up with the market need and, in most cases, with government rules as well. Part of these entities includes the higher education sector in which digital transformation did not become an option to run the business cycle. Especially after the COVID-19 pandemic, higher education institutions (HEIs) are being impacted by the Fourth Industrial Revolution's technological advancements, which necessitates adapting

to a digital transformation across all aspects of their operations. Incorporating digital technologies such as artificial intelligence (AI), machine learning, big data, and the Internet of Things (IoT) into different sectors and industries characterizes the Fourth Industrial Revolution. The education sector, including higher education institutions (HEIs), is not exempt from this impact [1]. Digital transformation has a remarkable impact on individuals and organizations in different industries and enterprises, especially in emerging markets as in the study country [2].

This alerts all decision-makers to digital transformation's significant role in the higher education sector. On the other hand, selecting a fully integrated solution to run enterprise operations became a difficult and risky decision for most enterprises. The integration of ERP systems with emerging technologies such as IoT, AI, and Blockchain is of paramount importance for businesses to enhance their functionalities and keep pace with the ever-changing business landscape. The incorporation of these technologies can lead to streamlined business processes, improved decision-making capabilities, and increased efficiency, ultimately helping businesses stay competitive in the market [3]. Building integrated systems is a significant cost item considering the Total Cost of Ownership (TCO) for the implemented software [4]. TCO should be considered as it is: a financial estimate that attempts to calculate an asset's total cost over its entire lifespan, including not only the initial purchase price but also ongoing costs such as maintenance, repairs, upgrades, and eventually disposal or replacement. TCO is often used in business and technology contexts to compare the long-term costs of different investments or strategies. By considering all the costs associated with an asset or investment, TCO can provide a more accurate picture of the true cost of ownership than simply looking at the purchase price alone. As per [5], you can expedite TCO analysis' importance in IT decision making and use it to provide a TCO analysis framework. The main objective of this study is to investigate the effectiveness of using enterprise architecture (EA) as a reference module for selecting the most suitable ERP system for higher education entities. To achieve this goal, the study proposes a set of research hypotheses that will be tested through a comparison technique and a case study of ABC University. These hypotheses include the impact of EA-based ERP selection criteria on reducing the risk associated with ERP selection, improving information flow and decision-making processes, enhancing operational efficiency and productivity, and aligning ERP packages with the current and future objectives of higher education entities. The main research question of the study is centered around identifying the essential criteria for selecting an ERP system and developing strategies to minimize the risk associated with the selection process.

Enterprise architecture (EA) supports entities in selecting solutions to easily run their business. Organizations often lack a clear overall view of their business functions, processes, information systems (IS), and individual technical platforms [6]. EA is a practice designed to align an organization's strategy, and the operating module defines how an entity should organize and manage itself to achieve its goals. Knowledge of enterprise architecture is an important part of properly developing an intelligent digital system [7]. EA offers a plan to support business transformation; it is a journey rather than a one-time project. The corporation needs to develop a sound strategy for digital transformation and evaluate it [8]. EA is not a specific solution, but it guides the organization to select the most suitable solution that fits its business. One of these core solutions is ERP, which has a significant core role in the organization as it covers most of the business cycle required to manage the administration process in the educational sector. However, additional solutions will be needed to cover the remaining process that handles the other industry-specific solutions in the educational sector. This will support fully automating those entities; EA will also support selecting an ERP solution in the educational entity and will be able to support extending the currently existing solutions in the case of business cycle changes or new processes surfacing. "EA and ERP systems are not equivalent concepts, yet they have many related and complementary characteristics" [9]. The ERP solution is

one of the main items that most organizations aim at implementing to control their business process flow in all administrative areas [10].

The study aims at setting the main criteria for the ERP selection in the high-educational sector based on EA to support the decision-makers in choosing the best suitable ERP system within their enterprise as long as the ERP selection is a very highly risky decision. Selecting the ERP based on the EA will mitigate the high risk and remove part of the uncertainty facing the decision-maker. It applies this set of criteria to a real ABC university as a case study using one of the modern smart EAs and builds a comparison between the ERP solutions to select the most suitable based on these criteria.

This study depends on EA reference models under the name smart university reference architecture (SURA), which is specifically designed by the Software Engineering Competence Center (SECC) as a benchmark for smart educational sectors [11]. SECC is a leading organization for ICT in Egypt, and it aims to support the local industry sponsored by the government represented in the Ministry of Communications and Information Technology (MCIT). The SECC has developed a complete assessment report for ABC University based on SURA. It depends on the SURA assessment report to select the most suitable solution for ABC University and results in a vision for a fully integrated software solution including the ERP as a core solution. Although a lot of research discusses ERP solution selection criteria, this study is unique as it adopts the EA's point of view. The current study does not only depend on selecting a standalone ERP solution but considers it as part of the solutions a whole organization requires to achieve the smartness concept.

The study's results indicate the best ERP solution that fits the education sector based on case study countries. The concluded results are supported by interviews with the key people in higher education entities that move in the same selected software showing the advantages and disadvantages of the chosen decision and lessons learned. This study constitutes the initial segment of a three-part series that will concentrate on operationalizing the concept of a smart education entity.

The next section explores the literature review. Section 3 overviews the EA concept and includes the SURA reference module and case study assessment result. In Section 4, the authors explain the study's proposed vision. Section 5 discusses the critical criteria for ERP selection; in Section 6, the ERP Shortlisted Solutions Comparison will be cleared. Finally, Sections 7 and 8 present the future suggested work and conclusion.

2. Literature Review

Several researchers have investigated the criteria for selecting an enterprise resource planning (ERP) system using different methodologies.

2.1. Factors Affecting ERP Selection

Bhatt et al. [12] propose a triangulation design to analyze the factors affecting the ERP system selection in developed countries. The Fuzzy Analytical Hierarchy Process and sensitivity analysis resulting from this research concluded that the cost of deployment is the main criterion following the user-friendly interface and security; lastly, vendor capability is the factor least affecting selection criteria. Zendehdel et al. (2020) [13] analyze the risk factors associated with the implementation and use of enterprise resource planning (ERP) systems over the past two decades, defining parameters and offering a comprehensive classification. It also highlights how these factors can affect the selection process of ERP systems. By considering these factors during the selection process, organizations can better assess the potential risks and benefits of different ERP solutions. Svensson and Thoss [14] focus on the challenges and risk factors associated with the implementation of ERP. By understanding the potential risks and challenges of ERP implementation, organizations can better evaluate and select ERP systems that are better suited to their needs and resources, ultimately improving the chances of successful ERP implementation.

2.2. Methodologies for Selecting ERP Systems

Noureddine and Oualid [15] provide a methodology showing a simple and practical method for using critical decisions to determine the selection criteria based on the organization's requirement selection, which will be decided in a clear way for all enterprise parties. Haddara [16] provides a selection method based on the organization's most critical business process, selecting from the potential ERP packages matching these processes by calculating the compliance degree and minimizing the risk of the selection process as well as the failure projects' consequences, following this with a case study for the ABC company to select the suitable ERP package with a technique named SMART referring to a simple multi-attribute rating. Efe [17] uses both the integration of fuzzy AHP (Analytic Hierarchy Process) and fuzzy TOPSIS (a technique to order preference using similarity to ideal solution) and a hydride module between both fuzzy AHP and fuzzy TOPSIS applying different decision-makers as recommended; the proposed methodology decreases the uncertainty with a group of decision-makers. Zaied and Mohmed [18] represent a road map for implementing ERP systems in small and medium enterprises (SMEs) showing the effect on the world economy and the benefit gained from applying ERP solutions in SMEs. Additionally, it shows the steps and guides to implement an ERP system in SMEs, which are considered a part not only of the success and failure of implementing the ERP but also of the research explaining the ERP selection criteria for the SMEs; different researchers' methods concluded that implementing the ERP in SMEs depends on their readiness assessment, which mainly includes team and infrastructure and involves proposing guidance to follow the assessment and make a decision.

As the ERP solution selection is a risky decision and has a high impact on both the success and failure of the organization's implementation, the study has multiple rankings of the selection criteria techniques to obtain direction and weightage for the selection basis and support decision makers as noticed by Yurtyapan and Aydemir [19] using a fuzzy technique, Lacurezeanu et al. [20] using the AHP selection technique for an integrated and sustainable ERP-solution-based SME, and Carpitella et al. [21], who applied a multi-criteria decision-making (MCDM) technique to obtain an assorted list of suitable ERP solutions. Table 1 shows the different ERP selection approaches used by different authors and the purpose of each used selection method. Hansen et al. [22] provides insights into the application of multi-criteria decision-making methods in the selection of enterprise resource planning (ERP) systems. The paper explores different methods for evaluating and selecting ERP systems based on multiple criteria, such as cost, functionality, and usability, to help organizations make more informed decisions about ERP selection.

Table 1. ERP selection approaches comparison.

ERP Selection Method	Purpose
Fuzzy Analytical Hierarchy [12,19]	An approach that allows for reasoning with uncertainty and imprecision. It involves assigning degrees of truth to statements.
Critical Business Process [15]	Involves identifying the critical processes that drive an organization's success and evaluating options based on how they impact those processes.
Organization's requirements selection [16]	This method involves identifying the organization's needs and requirements and selecting options that best meet those needs.
Fuzzy TOPSIS [17,20]	The multi-criteria decision-making method considers uncertainty and imprecision. It uses fuzzy sets and linguistic variables to determine the best alternative among a set of options based on a set of criteria.
Critical Criteria [23,24]	Identifying the critical criteria that need to be considered in a decision-making process and evaluating options based on how well they meet those criteria.

2.3. Criteria for Selecting ERP Systems

Polivka and Dvorakova [23] proposed a set of criteria that can be decision support criteria from an industry perspective depending on the ERP solution as part of the massive development of information called 4th generation industry. The current study considers it here as it shows criteria from a business and economic perspective helping IT managers have a simple set of initial criteria to check their readiness for implementing and selecting the ERP solution's suitable package, especially in the initial stages of selection. Polivka and Naveed et al. [24] provide critical criteria for selecting the ERP, but they are only specific for ERP that works on cloud solutions where they show the overall vision to be integrated with the IoT solution; they build ranking and evaluating techniques for the CSF for the cloud ERP system using the Analytic Hierarchy Process and Fuzzy Analytic Hierarchy Process. They also provide the CSF's guidelines and weightage for the cloud ERP that facilitates the decision-makers' CERP selection and achieves their strategic objective. Some studies touched on ERP's cloud part and cloud SaaS services as in Fallatah and Ikra [25], who provide a ranking system for the cloud services provider from the type SaaS (software as service). López and Ishizaka introduce [26] a group of criteria for selecting the best cloud ERP solution and supporting the decision-makers.

2.4. EA and ERP Selection

Eseryel and Wolff [9] show how the EA minimizes the ERP selection risk via the EA documentation, which is a reference for the ERP selection as they describe the organization's business vision and strategy in addition to the technology planning. Moreover, EA facilitates the link between the organization's goals and the ERP selection as well as concluding that EA can be used to achieve the best-fit ERP solution matched with its goals and initiatives. Singagerda [27] used the Open Group Architecture Framework (TOGAF) as an EA methodology to provide a framework for enterprise software development and used it to support ERP implementations in Indonesian private universities, concluding that EA has supported the academic and non-academic aspects of higher education to build their information system from all domains including data, information, application, business, and technology.

According to the literature review, the below table visualizes the most used techniques used to support the ERP selection decision.

Despite all the techniques focusing on ERP selection issues (including Fuzzy Logic, Analytical Hierarchy, and Ranking Technique), no study has dealt with it from the EA point of view, especially in the education sector. No doubt ERP systems are a valuable asset for any organization due to their ability to manage and cover various business cycles across different departments. However, many researchers overlook the fact that an ERP system should be considered part of the entire enterprise architecture (EA) module. This approach enhances the value of the ERP system and integrates it fully, allowing it to cover all enterprise business processes. Consequently, organizations can achieve higher efficiency, productivity, and competitiveness. Therefore, the research aims to investigate how enterprise architecture (EA) can assist in the selection process of ERP systems within the educational industry, using ABC University as a case study. It will not be limited to this scope but will also move to an ERP sample process implemented in one of the high educational entities and explore the advantages and disadvantages of the study result.

3. EA Concept

EA became a supportive element for organizations that aim at determining how they can achieve their current and future goals. It represents a vision for the enterprise details from the most generic architecture to specific software solutions. EA has theoretical and methodological roots in business, strategic, and technological planning. These include strategic plans, operational scenarios, business process models, data models, documentation on applications, networks, and IT security [6]. According to the TOGAF standard,

there are four architectural domains, as shown in Figure 1, based on the TOGAF reference material [28].

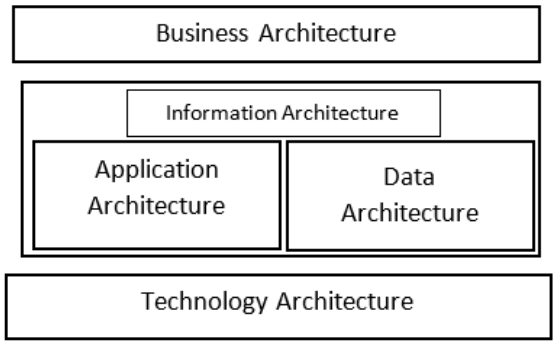

Figure 1. EA architecture types.

Business architecture describes the overall business strategy and the principal business process. A data architecture describes the organization structure from the logical perspective, the physical data set, and management. Application architecture not only provides details for all the applications that are deployed in the organization but also shows how it interacts with others and how it serves the principal organization's business process. A technology architecture describes the software and hardware required to deliver and operate all the business operations and services; this includes IT infrastructure, networks, middleware, and communications. The main purpose of enterprise architecture is to align an enterprise to its essential requirements. Its meaning is that it provides a normative restriction of design freedom toward transformation projects and programs [29].

4. SURA Reference Module

SURA (smart university reference architecture) is an EA reference module for the higher education sector; it was developed by SECC as a leading organization for ICT in Egypt, and it aims at supporting the local industry sponsored by the government represented in the MCIT [11]. SECC has merged with ITIDA as a governmental entity, which has the same aim of growing the different industry sectors in Egypt via IT. SURA was officially released in January 2019, and it is designed as an EA reference module for higher education universities; it represents a roadmap and benchmark for smart universities. As smartness in education is no longer just an option but is currently reshaping the learning experience all over the world, the main idea behind SURA is to categorize the requirements for a university that aims to have smart capabilities. Each capability represents a target point to achieve a smart vision. SURA focuses on six main pillar capabilities, with each one consisting of a set of subsidiary capabilities. The SURA EA reference module's principal capabilities are listed as follows: Smart Learning, Smart Assessment, Smart Classroom, Smart Support, Smart Operations, and Smart Campus. SURA also represents around 34 detailed capabilities, and the following Table 2 shows each pillar's detailed capabilities.

Table 2. SURA detailed capabilities.

SURA Main Pillar	Detailed Capabilities
Smart Learning	Authoring, Digital Media Library, Content and Material Management, Class Management, Student Research Support, Communication, Collaboration, Virtual Lab, and Digital Certificate.
Smart Classroom	Smart Classroom.
Smart Assessment	Assignment Management, Formative Assessment, and Test Management.

Smart Operation	College Management, Library Management, Digital Archiving, Digital Marketing, ePayments, Porter Management, Student Transportation, and Logistics and Warehousing.
Smart Support	Technology Transfer and IP Management, Entrepreneurship, International Relations, Academic Advising and Tutoring, Administrative Support, Medical Support, and Data Analytics.
Smart Campus	Security and Surveillance, Connectivity Management, Access Management, Environment Management, and Building and Facility Management.

5. Research Methodology

The authors used a case study at ABC University as a realistic case study. Explanatory case studies are useful in presenting cases when exploring new phenomena or when there is a lack of theory [30]. The explanatory case study method is recommended when "how" and "why" questions are postured [16]. The qualitative case study methodology enables researchers to conduct an in-depth exploration of intricate phenomena within some specific context. This article offers a methodical and comprehensive approach to performing case studies within the business discipline [31]. A major advantage of using case studies is their potential to generate new theories [32]. The purpose of this research is to minimize the risk of selecting the ERP solution for the education sector given EA by discussing the most effective selection criteria. The model can be used with different case studies; however, each criterion will have a specific weight based on the case requirement. *The weighted scoring SMART* (simple multi-attribute rating technique) analysis is commonly used as an ERP selection technique among Egyptian organizations [33]. This study aims also to represent clear comparison data for the different ERP packages and provide guidance for educational entities that need to take follow the same selection process and receive recommendations according to their case.

5.1. Research Data

The study depends on different data sources including two main data sources. The first source is the SURA assessment, which is performed using two main methods. The first is an onsite workshop, and the second is an offsite questionnaire with the responsible parties for each assessment area in the university; all the information was consolidated by SECC, and it provides both evaluation results and recommendations. The assessment includes more than 75 stakeholders from university staff who participated in the different sessions with contributions from the university board members, and the required permission was issued to use the report data as part of the current study. The second data source for this study comprises four interviews with key individuals responsible for managing ERP implementation solutions in their educational institutions in Egypt. The author took detailed notes during interviews that lasted between 30 and 60 min. The primary objective of these interviews was to explore the challenges related to ERP implementation, from the selection process to post-implementation support.

The author was granted convenient access to all necessary resources to ensure the successful completion of this research. This includes access to the detailed assessment report for the case study conducted by SURA as well as all selection criteria provided by SECC. The author also consolidated useful selection criteria obtained during the interviews. In addition, the author has access to various ERP package documentation and technical and financial proposals documents provided to the case study university by different ERP vendors, including detailed information on each vendor's functionality.

5.2. ABC University

ABC University is small size university based in Egypt that handles nine colleges and two institutes as subsidiary entities. It had around 35,000 students enrolled in its various academic programs as of the research data. ABC University is an entity that works to develop its digital transformation plan to have full control of its learning services and

administration activity following the most practical and professional standards in the information technology field to achieve its strategic vision of smart learning. As per the assessment conducted by the SECC organization, ABC University has already been evaluated using 34 SURA capabilities, and the assessment results are available. The university aims to select and implement the most suitable ERP solution package based on the evaluation results to achieve its smart vision and address the gaps identified in the assessment.

5.3. Research Data Analysis

Table 2 includes the assessment results based on the 34 capabilities, as the overall output results are provided by the SECC to the university with all assessment criteria for the highlighted capabilities. ABC University was evaluated toward each SURA capability, and as demonstrated in Table 3, each capability receives one of the following statuses:

(A) Almost/Partially Complete: most of the services exist/partially exist and with good use of technology.
(B) Complete: some services of the capability exist but with insufficient technology.
(C) Missing: the capability, including its services, is completely or largely missing.
(D) Manual: the services are there, but every service uses outdated or no technology.

Table 3. Collective assessment results.

Main Pillar	Detailed Capabilities	Missing	Partially Completed	Manually
Smart Learning	Authoring, Digital Media Library, Content and Material Management, Virtual Lab, Collaboration, Digital Certificate	✓		
	Class Management, Student Research		✓	
	Communication			✓
Smart Assessment	Assignment Management, Formative Assessment, Test Management			✓
Smart Classroom		✓		
Smart Support	Technology Transfer and IP Management, Entrepreneurship, International Relations, Alumni Support, Medical Support			✓
	Academic Advising and Tutoring, Data Analytics	✓		
	Administrative Support		✓	
Smart Operations	College Management			
	Library Management, Porter Management, ePayments		✓	
	Digital Archiving, Digital Marketing	✓		
	Student Transportation, Logistics and Warehousing			✓
Smart Campus	Connectivity Management	✓		
	Access Management, Security and Surveillance, Environment Management, Building and Facility Management			✓

According to the provided assessment results, a detailed report for each capability was provided to the university to justify the results. The authors have access to the detailed report of SURA evaluation. However, we will not go into much detail for each criterion, as the study concern is to select the most suitable ERP that can cover the shortage exist in the evaluation result. ABC University considers this assessment as a benchmark to select the suitable integrated solutions to fulfill a smart university's vision.

6. Study Proposed Vision

In this section, the study will propose a solution architecture that will be presented referring to the ABC University assessment results. As shown in Table 3, there are 5

partially completed items, 17 manual capabilities that work in a non-computerized way, and 12 missing capabilities. This study aims to achieve and cover the weak areas that can be covered by software solutions in one integrated platform to achieve the SURA vision of a smart university. Thus, the ERP concept appeared on the surface as it achieved the main concept for the integrated components that work together.

The proposed vision describes most of the functionality that can be part of the smart educational industries based on the SURA reference module. The proposed vision is inspired by the ERP solution as it works as an integrated module and does not work as separated islands. This action solves a lot of data scattering problems and supports high management performance and data availability on time.

Figure 2 represents part of the standard ERP core solution that includes Financial Accounting, Inventory, Procurement, Maintenance, and Human Resources; the other module represents the proposed solution for the front-end office requirements for ABC University that can be integrated to complete the smart vision: portals, LMS (learning management system), the libraries system, student affairs, graduation affairs, postgraduates and integration with IOT devices and sensors. IoT integration with ERP for smart universities will be part of another study as part of the smart university study chain that is in the process to be published by the same authors.

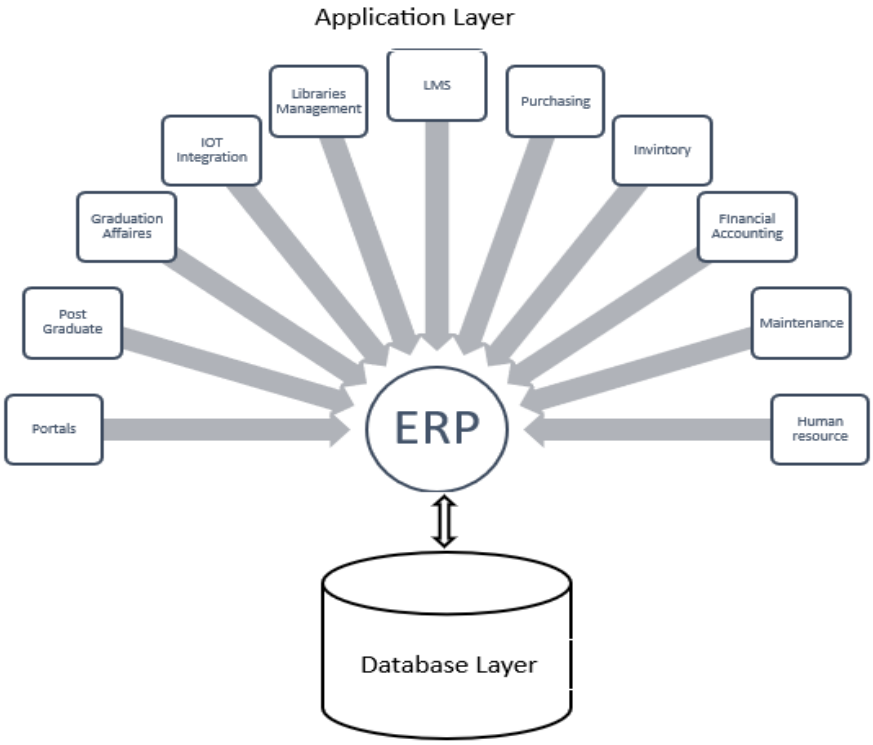

Figure 2. Education industries' ERP proposed solution architecture.

The author proposed this initial vision based on ABC University's requirement given the SURA capabilities. Other capabilities that are not related to the IT area and cannot be achieved through a software solution will not be part of this study.

According to the ABC University assessment result in Table 3, all the administrative operations are manually performed in an old fashion in addition to most of the other educational solutions being totally missing or partially completed and them working separately. Based on this assessment, the study aims not only to select the ERP solution package that can achieve the administrative part but also to extend to other software packages in an integrated way that represents fully integrating the proposed architecture. This aims to achieve the boundary-free information flow, and it covers areas to reach the smart

university according to all the required capabilities for SURA. It can also be extended to other valuable packages to achieve different added value within SURA as an EA benchmark.

The main challenge is that the ERP was originally designed for the manufacturing industry, not for the educational sector. Thus, it only covers the administration scope related to the university back office, with most ERP packages having the administrative part as a ready-made solution but not all having the ability and flexibility to extend to other solutions to achieve the proposed solution architecture shown in Figure 2. The proposed vision of the ERP plays a significant role in achieving the smart concept. The ERP system package is a risky decision for any organization and its decision-makers because it affects the whole organization's progress. Thus, its selection process should be scientific and professional. For small and medium-sized enterprises, the adoption and implementation of enterprise resource planning (ERP) systems poses a significant challenge. The primary issue is that the expenses associated with customizing the ERP system to align with the enterprise's specific business processes exceed the cost of acquiring the ERP system [34].

The primary method used in the selection process was process mapping, which was combined with a structured multi-criteria evaluation based on literature and practical experience in the field. In addition to considering factors such as the size of the organization and contextual dimensions, the evaluation and assessment process focused on 9 main factors: ERP system functionality, business process mapping with the ERP package, technical criteria, cost and budget, service and support, vision, system reliability, compatibility, market position, modularity and integration, implementation methodology, as well as organization size and context [16].

The authors follow a brainstorming technique performed by the authors themselves to generate the most critical selection criteria for selecting an ERP solution given the EA (SURA) as it is the main standard reference module and benchmark for the same industry in addition to the criteria obtained from the interview process.

7. ERP Package Comparison Based on Main Selection Criteria

In this section, the authors compare the ERP solutions that are being selected by ABC University given the nine highly effective selection criteria, including Product Functionality, Implementation Methodology, Implementation Time, Cost, Sustainability and Scalability, Configuration Complexity, Used Programming Language Popularity, Technical Criteria, and Partner Support.

The study aims to compare SAP (A), ORACLE (B), Microsoft (C), and ODOO (D) as shortlisted ERP packages selected by ABC University.

The shortlisted solution is selected based on ERP's most common problems, which are considered as follows: Data and Software Quality Issues, Poor Usability, Integration, Interoperability, Security Standards, Monitoring Requirements, Levels of Customization, Requirements of Industry, Cloud ERP, and Customization Requirements; all these criteria are considered according to the ERP problem research agenda [35]. Below, Sections 7.1–7.9 study will explore each criterion and will compare the four ERP packages against each one of them as follows.

7.1. Product Functionality

Product Functionality is one of the main selection criteria as it should include all the business process cycles at ABC University; a comparison is shown in Table 4.

Table 4. Product Functionality comparison.

Package	Details
A	SAP S4Hana Package includes the main required package (financial controlling, material management, purchasing, human capital, and plant maintenance).
B	Oracle also has its E-Business Suite including applications that cover financial, procurement, human capital management, logistics, and services.
C	Microsoft has its Microsoft Dynamics ERP including finance and operations, field service, supply chain management, and human resources.
D	Odoo software has multiple applications in its last version include (finance apps, inventory, manufacturing, and human resources apps).

All four ERP packages mainly have most of the required functionality that can be used in the administrative part of the educational sector's core, including financial and controlling, human resources inventory, and purchasing and maintenance. One disadvantage for all shortlisted ERP solutions is that they do not cover any industry-specific solutions for the higher education sector.

7.2. Implementation Methodology

Implementation Methodology refers to the structured approach that consists of procedures, processes, and practices used to effectively execute a project or initiative. It involves a comprehensive and systematic plan that outlines the necessary steps and resources required to achieve the desired outcomes within the specified timeframe and budget. A well-designed implementation methodology helps to ensure that the project is completed efficiently and effectively while meeting the objectives and requirements of the stakeholders. The comparison is shown in Table 5.

Table 5. Implementation methodology comparison.

Package	Details
A	SAP depends on Activate Methodology including phases as below (Prepare, Explore, Realization, and Deploy and Go Live).
B	Concerning the Oracle part, segregates phases into the following stages: Stage 1: Engage Stage 2: Drive, Stage 3: Enable, and Stage 4: Convert.
C	Microsoft Dynamic 365 implementation lifecycle consists of four methodology phases: Stage 1: Initiate, Stage 2: Implement, Stage 3: Prepare, and Stage 4: Operate.
D	Odoo software also has its practice and methodology; it is divided into phases as follows including the percentage for each: Business Need Analysis (15%), Full Featured Prototype (15%), Data Import and Specific Development (50%), Validation and Training (10%), and Deployment: Go Live (10%).

In general, all four packages have known implementation methodologies with some variance in the terminologies and minor concepts but all, in the end, have the same target.

7.3. Implementation Time

Implementation Time refers to the duration of time it takes to complete the implementation of a project or initiative. The implementation time can vary depending on several factors, such as the scope and complexity of the project, available resources, budget, and the methodology used for implementation. The comparison is shown in Table 6.

Table 6. Implementation Time comparison.

Package	Details
A	There are no high-level variances between all four solutions concerning the implementation time.
B	However, Odoo's software may have less complexity to download and implement with only one
C	or a maximum of two consultants being required for the implementation, which impacts posi-
D	tively the overall implementation time.

7.4. Sustainability and Scalability

Sustainable practices can help ensure that a business is better positioned to grow and scale over the long term. Scalability, on the other hand, refers to the ability of a system or process to handle increasing demands or growth without a significant increase in cost or decrease in performance. A comparison is shown in Table 7.

Table 7. Sustainability and Scalability Comparison.

Package	Details
A	All four shortlisted ERP packages are selected as reliable solutions, and their providers have a high market position, so all are sustainable enough. In addition, all four packages are modular wise and able to integrate with the other legacy systems; all the ERP packages allow customizing the existing functionality to be adapted to the special business requirement. However, Odoo has a more competitive advantage in that it is an open-source code which gives more flexibility in extending the solution.
B	
C	
D	

7.5. Cost

The Cost factor in ERP selection refers to the financial investment required to implement and maintain an enterprise resource planning (ERP) system. ERP systems can be expensive to purchase, customize, implement, and maintain, and the cost of ERP implementation can vary depending on several factors, such as the size of the organization, the complexity of the business processes, and the level of customization required. A comparison is shown in Table 8.

Table 8. Cost comparison.

Package	Details
A	SAP has three types of products; in this study, we discuss the SAP ALL in one (S4Hana) for large enterprises as it better fits with the research proposal. It requires a substantial budget (IT footprint; annual license; SAP user; and Personnel), and a higher total cost of ownership (TCO). It also requires a team of Database Administrators (DBAs), a Basis Consultant, and Functional Consultants (at least three consultants). The starter package of five users (USD 5000) + one developer (USD 9000) + one professional (USD 5000) + 22% annual maintenance (total cost of USD 45,000; rough before partner discounts), excluding H/W costs [16].
B	According to Oracle E-Business Suite Applications Global Price List 7 June 2022, Software Investment Guide; Oracle sells its product for around USD 5000 per module; the minimum is five users in addition to USD 1000 for Software Update License and Support [36].
C	The Starter Pack is USD 5000 and includes a financial model to control expenditures and cash flow, a distribution module to purchase and sell materials, services, and items, access for three full users, payroll, and human resource modules to manage the unlimited employee number. There are two available licensing options: essential or premium. The pricing aligns with the number of users and costs USD 70 per user/month for the essential license plan and USD 100 per user/month for the premium plan (Business Central Pricing | Microsoft Dynamics 365, 2021) in addition to the cost of technical infrastructure, implementation, and support [37].
D	Odoo ERP costs an average of USD 8/Month per module for only one user and allows for cloud hosting and self-hosting. Odoo is an open ERP system that allows for extensions and it also codes modification in case it is required; it has pros and cons that will be discussed in the next sections [38].

7.6. Configuration Complexity

Configuration Complexity refers to the level of difficulty or intricacy involved in setting up and configuring a system or application. This can include configuring hardware components, software applications, network settings, security settings, and other

parameters that may be necessary for the system or application to function properly. Measuring system configuration complexity in an ERP system can be achieved by considering factors such as the number of modules and functionalities that need to be configured, the degree of customization required to meet specific business needs, the level of integration with other systems, and the overall complexity of the business processes being automated. A comparison is shown in Table 9.

Table 9. Configuration complexity comparison.

Package	Details
A B C	A, B and C packages almost have the same complexity configuration level and require consultation to configure and set the system to be ready for work [39].
D	Less complexity and requires few numbers of a consultant to set up; in a few cases, configurations are easy that enable the normal user to set up and configure different applications; the package also comes with an easy UI/UX interface [40].

7.7. Programming Language Popularity

When we refer to a programming language as "popular", we typically mean that it is widely used and has a large community of developers and users. Popular programming languages tend to have a range of libraries and tools available, making it easier to develop software using those languages. The below table will show the programming language ranks concerning the TIOBE Index for April 2023. The ratings are based on the number of skilled engineers world-wide, courses and third-party vendors [41]. A comparison is shown in Table 10.

Table 10. Programming Language Popularity Comparison.

Package	Used Programming Language	Position	Rate%
A	Advanced business application programming "ABAP"	49	0.17
B	SQL/PLSQL	8	1.68
C	Visual Basic	6	14.51
D	Python	1	14.51%

Concerning the above, python is the most popular programming language and comes in the first position.

7.8. Technical Criteria and Package Fit

Several Technical Criteria that should be considered during ERP include system architecture, technology platform, security, technical support and training and used hardware.

All four packages are well-reputed, have well-known security and can have a multibed platform to enable access (mobile, web and tablets); however, part of this package requires a higher IT footprint among others as follows. A comparison is shown in Table 11.

Table 11. Technical Criteria and package fit comparison.

Package	Details
A	Requires more complicated, as well as higher IT footprint.
B	The package fits large-scale organizations.
C	Medium complexity, as well as medium IT footprint. The package suits small and medium organizations.
D	Require a simple IT footprint. The package fits small and medium organizations, which better suits ABC University.

7.9. Partner Support

Generally, Partner Support refers to the assistance and resources provided by ERP implementation partners or resellers who work with customers to implement and support ERP software, in which the vendor support customer is implementing the initial system with experts and consultants and during the support phase post to the implantation. A comparison is shown in Table 12.

Table 12. Partner Support comparison.

Package	Details
A	All four packages have a good market position in Egypt as a research country, and each package has a well-reputed support partner.
B	
C	
D	

All four ERP software packages were evaluated against the evaluation criteria as presented in the previous section; after finalizing the selection process, recommendations are provided for ABC University to use the Odoo ERP system. ABC selects Odoo as a private cloud solution hosted by Odoo company itself to minimize the security issues and minimize the required IT footprint.

Although all four ERP packages can be implemented in ABC University, the university decided to go through selected packages as they can achieve SURA vision in sustainable mode with a great ROI because it is open source and has a popular programming language; thus, it will facilitate the flexibility for a customization and integration process. Table 13 shows a summary table of the selection criteria and how the criteria match with ABC University.

Table 13. Selection summary.

No.	Criteria	A	B	C	D
1	Functionality	✓	✓	✓	✓
2	Implementation Methodology	✓	✓	✓	✓
3	Implementation Time				✓
4	Cost				✓
5	Sustainability and Scalability	✓	✓	✓	✓
6	Configuration Complexity				✓
7	Popular Programming Language			✓	✓
8	Technical Criteria			✓	✓
9	Partner support			✓	✓

The results of this study provide support for the research hypotheses, which aimed to investigate the effectiveness of using enterprise architecture (EA) as a reference module for selecting the most suitable enterprise resource planning (ERP) system for higher education entities. The study proposed a set of critical criteria for ERP selection as a core solution in the education sector, which was based on an EA reference module specifically designed for higher education entities that seek to operate smartly. A comparison technique was employed to evaluate the highlighted criteria, including a case study for ABC University.

The first hypothesis suggested that the use of EA as a reference module for ERP selection would result in a more effective and efficient digital transformation of higher education entities. The study's results support this hypothesis, as the EA reference module provided a comprehensive view of the higher education entity's operations and identified the critical criteria required for selecting a suitable ERP system. This enabled the entity to

make a well-informed decision about the most appropriate ERP system that aligned with its current and future objectives.

The second hypothesis proposed that the adoption of EA-based ERP selection criteria would significantly reduce the risk associated with ERP selection as a core solution. The study's results support this hypothesis, as the EA reference module helped identify and evaluate the critical criteria required for selecting a suitable ERP system. This reduced the risk associated with ERP selection by ensuring that the selected ERP system aligned with the entity's current and future objectives and avoided complex challenges caused by unmanageable information flow blockages.

The third hypothesis suggested that a fully integrated and sustainable solution envisioned for higher education entities based on a smart EA reference module and critical ERP selection criteria would lead to improved information flow and decision-making processes. The results of the study support this hypothesis, as the EA reference module and critical ERP selection criteria enabled the higher education entity to select the most appropriate ERP system and related solutions integrated with the ERP system under the EA umbrella. This resulted in a fully automated smart entity that supported improved information flow and decision-making processes.

The fourth hypothesis proposed that the implementation of EA-based ERP systems in higher education entities would result in improved operational efficiency and productivity. The results of the study support this hypothesis, as the selected ERP system and related solutions integrated with the ERP system under the EA umbrella improved operational efficiency and productivity by providing a clear strategy for digital transformation and seamless information flow across boundaries.

Finally, the fifth hypothesis suggested that the adoption of EA-based ERP selection criteria would enable higher education entities to select the most appropriate ERP package that aligns with their current and future objectives. The study's results support this hypothesis, as the critical ERP selection criteria identified through the EA reference module enabled the higher education entity to select the most suitable ERP package aligned with its current and future objectives.

8. Study Limitation

The study has limitations as it only covers one case study and one evaluation-report-based SURA for ABC University; SURA is effective as an EA reference module for the educational sector in the study country but may not be suitable for other educational entities in different countries or studies focusing on selecting an ERP-based only education entity as the main focus. However, the same module can be used as guidance for other industries.

9. Future Proposed Work

This study opens new opportunities for future research to investigate the most effective selection criteria for ERP-system-based EA reference modules not only for the education sector but for different industries. The research opens the gate for future studies that will focus on building a smart educational industry to use SURA as a reference benchmark and be part of their digital transformation journey. It proposes applying investigation to the ERP implementation challenges in the education sector and provides solutions for smooth implementation with minimal risk. Future researchers can work on studies that cover the implementation challenges facing projects, specifically the integration between the core ERP system and other industry-specific solutions that do not cover the ERP modules.

10. Conclusions

Digital transformation has become essential for all entities to adapt to market changes. Most universities in the education entities work to achieve the smart university

concept as part of their digital transformation journey. The smart approach uses technology and data-driven methods to enhance the learning experience; it involves the use of digital tools, such as computers, tablets, and smartphones, to access educational materials and collaborate with others. SURA became the reference model and the latest benchmark in the study country for smart universities developed by SECC. The ERP concept appeared on the surface as it achieved the main concept for the integrated component that works together for creating fully integrated software that serves the smart university concept.

The study used ABC University as a case study that aims to apply the smart university vision and allows researchers to focus on it as a current phenomenon that occurs in a real-life context. ABC University was subject to SURA evaluation against six main smart capabilities and 34 detailed sub-capabilities, which was performed by the SECC organization. According to the evaluation ABC University realized the importance of implementing an ERP solution. This study proposes a solution architecture structure that matches the overall university smart vision in which an ERP solution represents the core platform for establishing a smart integrated platform that supports all university operations and the SURA vision toward embracing the smart university concept.

The study proposes an ERP selection process to guide ABC University to the selection of the best suitable ERP package that can achieve its vision. The study compared four ERP packages that were shortlisted by ABC University against nine criteria using a simple multi-attribute rating technique. The four results were summarized and weighted to obtain a score. An investigation conducted in Egypt by researchers indicated that the selected package is commonly used as an ERP solution in five similar educational entities. Part of the investigation indicated that other different educational entities need to have the same smart vision, which this study will support as practical guidance. The recommendation report was provided to ABC University board members to finalize the selection decision, and it is currently under an approval process.

In conclusion, the findings of this study suggest that the use of EA as a reference module for ERP selection in higher education entities can be effective and efficient, reducing the risk associated with ERP selection as a core solution and supporting digital transformation. The study provides critical criteria for ERP selection as a core solution in the education sector and highlights the benefits of a fully integrated and sustainable solution based on a smart EA reference module. Future research should focus on addressing the potential limitations of this study, such as the small sample size and the lack of generalizability to other sectors and exploring the effectiveness of EA-based ERP systems in other contexts.

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