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Reconceptualizing Enterprise Resource Planning (ERP) Systems from a Software Architecture Perspective Using a Framework Based on ERP System Characteristics

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Abstract

The term "*Enterprise Resource Planning (ERP) System*" is commonly used by academics and practitioners in business and information systems. This research reveals two interpretations of the term ERP system, which implies that defining ERP systems comprehensively poses challenges, prompting a focus on their inherent characteristics. Using Design Science Research Methodology, this study aims to provide clarity by introducing a continuum framework that categorizes ERP system implementations based on their software architecture and ERP system characteristics. The framework serves as a guiding tool, enhancing understanding of ERP systems and facilitating ways to increase efficiency and effectiveness. To illustrate its practical utility, the framework is applied in a case study context. The paper concludes by identifying avenues for future research and addressing inherent limitations.

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Keywords: Enterprise Resource Planning System; ERP; ERP Characteristics; ERP Categories; Understanding ERP System; ERP Framework

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1. Introduction

The term **Enterprise Resource Planning (ERP) System** or **ERP System** is widely used by academics and practitioners in the field of information systems, management information systems, and computer science to designate the concept of "*integrated*" systems. There is no consensus among researchers regarding the definition of an ERP system [1], and multiple definitions have been used in the literature, each tending to cover distinct facets of ERP systems depending on the research questions studied by the authors [2-7]. For instance, Tadjer in 1998 defined ERP as "*one database, one application and a unified interface across the entire enterprise*" [8]. Klaus, Rosemann and Gable [3] explained ERP systems as "*comprehensive, packaged software solutions that integrate all business processes and functions; to present a holistic view of the business from a single information and IT architecture*." They viewed ERP as a commodity, infrastructure, or development objective to map all business processes into enterprise architecture. Davenport explained an ERP system as "*an enterprise-wide IS, which facilities the information flow and coordinates all activities and resources within the organization*" [9, 10]. ERP systems has been described by the phrase "*in the eyes of the beholder*" by Klaus, Rosemann and Gable [3] and they confirmed that it is challenging to arrive at a complete definition. Nevertheless, there is a consensus among researchers on the characteristics of ERP systems [11]. For example, they are perceived to be software packages, integrated, centralized, spanning across the organization, multifunctional, capable of handling real-time data, and sharing information.

1.1. Understanding Gaps in Knowledge

Although the topic of ERP is well-established with over 40 years of literature, there appears to be a knowledge gap in understanding ERP systems that requires addressing. For instance, the term "*ERP systems*" presented in the literature can be interpreted in two ways from a software architecture perspective [11].

First, ERP system can be seen as a **centralized database** that integrates multiple systems from the entire organization with different interfaces and segregated databases. Evidence for this can be found in literature where authors describe ERP systems as "*getting all systems to talk to each other*" [9], "*multiple software integrated into one package…..combine all functional areas of an organization into one real-time database*" [12]. Davenport further asserted that "*an enterprise system is a central database that draws data from and feeds data into a series of applications supporting diverse company functions*" [10]. Another author defined ERP as "*IT infrastructure that integrates different information systems….*" [13]. These definitions portray ERP system as a technical integration tool i.e., centralized database to combine different multiple systems.

Second, ERP systems can be interpreted as a **single system** with a unified interface and centralized database that spans the entire organization and covers all key business functions. This perspective is supported by literature citing ERP systems as "*single IT architecture infrastructure*" [3], "*single software system using a single data repository*" [14], "*incorporated system that allows for a single information flow, continuous and consistent for the whole company under a unique database*" [15], and "*software package that hooks up all functional departments into a single unified information system*" [16]. These definitions portray ERP as a single software system that integrates multiple departments across an enterprise.

One can argue that regardless of the interpretation and approach used for an ERP system —whether by connecting multiple systems through the use of a centralized database or by using a single system for the entire enterprise—the organization can benefit from having an ERP system and enjoy the integration, modularity, scalability, transversality and other benefits provided by implementing an ERP system. But that is not entirely true. Sneller presented several cases where large companies use two different ERP systems in their organizational software architecture [17]. This suggests that ERP systems, despite being labeled as all-inclusive, may not fully meet the needs of organizations. On some instances, organizations might need to implement more than one ERP system to meet their business functional requirements. Furthermore, Kähkönen, Smolander, and Maglyas stated that "*it is essential to integrate ERP with other business information systems both inside and outside the organization*" [18]. This indicates that ERP systems may not always fulfill the comprehensive integration they promise. Therefore, there is a need for a more nuanced understanding of how ERP systems serve the organizational needs within its software architecture to fully harness their characteristics for enhanced efficiency and effectiveness.

1.2. Research Purpose and Structure

It is understood that even though two organizations may implement the same ERP system, the implementation within each organization's software architecture is unique and based on specific business requirements. Therefore, it is crucial to understand how an ERP system, as implemented within the software architecture, serves the organization's needs. For instance, merely having an ERP system does not guarantee full enterprise-wide integration. Similarly, even though ERP systems are known to imbed industry "*best practices*," this does not automatically apply to an organization that implements them. An organization's software architecture must be evaluated on various ERP characteristics such as integration, modularity, scalability, and transversality to gain the full benefits of the effectiveness and efficiency promised by the ERP system.

The purpose of this research is to help academics and practitioners evaluate whether the ERP system implemented within the organizational software architecture functions as a fully integrated system that fulfills all the characteristics of an ERP system and provides the anticipated benefits. This research proposes a framework consisting of various software architectures for implementing ERP systems aligned with ERP characteristics. This study contributes to the literature on ERP systems in two ways: first, by providing a framework to evaluate the inherent characteristics of ERP systems in organizations that have implemented them; and second, by applying this framework to a case study to demonstrate its practical utility for academics and practitioners in assessing ERP systems.

The structure of the paper is as follows: The next section is the literature review, where we will examine existing research in this area. Following that, we will detail the methodology used for this research, present the findings and contributions, and conclude by discussing limitations and suggesting future research directions.

2. Theoretical Background and Literature Review

This paper examines ERP system implemented in an organization from a software architecture perspective. It uses the definition of software architecture provided by the Rational Unified Process (RUP), which defines it as the "*set of significant decisions about the organization of a software system, the selection of the structural elements and their interfaces by which the system is composed together with their behavior as specified in the collaboration among those elements, the composition of these elements into progressively larger subsystems, the architectural style that guides this organization, these elements and their interfaces, their collaborations, and their composition*"[19]. Therefore, the literature review conducted in this paper will explore the ERP system from the perspective of software architecture.

The primary objective of conducting the literature review was to investigate similar research on the software architecture perspective of ERP systems. Therefore, it explores different ERP system categories or classifications, examines the characteristics of ERP systems, and identifies any frameworks for understanding ERP systems presented in the literature. The database sources used for the literature review included Google Scholar, the University of Sunderland Library Database, and the ResearchGate website. The search terms included "*ERP Software Architecture*", "*ERP System Characteristics*", "*ERP System Categories/Classifications*", and "*ERP System Framework*". Based on the literature review findings, this section will be divided into three parts. First, we will investigate if any research was conducted to gain a better understanding of ERP systems, i.e., different ways or classifications/categories of ERP systems within an organization's software architecture to fully harness their characteristics for enhanced efficiency and effectiveness. Then, we will present the literature that focused on the characteristics of ERP systems. Finally, any works related to frameworks within ERP system research will be presented. The terminology often interchanged with the term ERP such as Enterprise System (ES) [10, 20, 21] and advance versions of ERP systems such as ERP II [22-26], ERP III [5, 24, 25], ERP IV [5, 24], i-ERP [2, 27], cloud-ERP [1, 26, 28-33], hybrid-ERP [34] and extended-ERP [24, 26] were all included as part of this search.

In terms of similar research on ERP categories, this research differentiates between the two ways ERP systems are implemented in an organization's software architecture as described in section 1.1. The literature search did not reveal any research that differentiates between the two interpretations of ERP systems as described in section 1.1. However, there are different categories of ERP mentioned in the literature based on ERP system development, advanced versions of ERP, classifications due to various business factors, and ERP transformation models. For instance, ERP systems also evolved alongside the use of the internet and is rebadged as ERPII and extended ERP, whereby businesses can connect their internal systems with those systems of suppliers [8, 22, 35, 36]. Moreover, the modernized version of ERP has been labeled as ERP III, ERP IV and i-ERP which features advancement of technology. Dziembek [24] has presented the differences between ERP, ERP II and ERP III. Moreover, the meaning of ERP IV is incorporated with the user of artificial intelligence, machine learning, big data, industry 4.0 and fog computing [24]. Likewise, i-ERP has been used for incorporating artificial intelligence with ERP systems where i stands for intelligence [2, 27]. The difference versions of ERP systems are distinguished based on the advanced technology used along with the ERP system, nevertheless it does not clarify the original intended meaning of ERP system. Vukovic et al. and Faizi et al. has presented a classification for ERP system into three to four tiers based on the certain factors such as size of the organization, the revenue of the ERP system supplier, the number of users targeted, and some other factors such as the functional complexity of the ERP system itself [37, 38]. Whereas, Aşan has presented an ERP Development Taxonomy where they divided ERP into basic ERP, general ERP, automatic ERP, semi-autonomous ERP, autonomous ERP, and intelligent ERP [2]. Dziembek presented a classification of ERP system into four types based on the way they are installed, constructed, functioned and implemented [24]. Asprion et al. proposed a new ERP transformation model that separates the decision indicators for investing in ERP systems into four categories using two dimensions i.e., people-centricity and integration [39]. The four categories are classical ERP, ERP separated from SoE (system of engagement), Enhanced ERP and ERP & SoE combined.

Since we intend to assess how many of the ERP system characteristics are inherent in organizations that have implemented ERP systems, the literature search in this area is essential. In terms of the characteristics of ERP System, it is claimed that ERP systems can be better explained by their characteristics and functions [3, 15, 24, 40, 41]. The characteristics of ERP system are presented in various studies [3, 15, 17, 24, 40-48]. Table 1 presents the characteristics of ERP systems taken from the literature. All researchers agreed that the main characteristics of ERP system is integration but for simplicity only some sources have been referenced in Table 1.

Table 1. Characteristics of ERP System from the literature

Characteristics	Meaning	Source
Integrated	The level of integration between different functions	[3, 17, 40, 46, 48-50]
Modular	Have modules for specific business functions	[3, 17, 40]
Generic	A single solution can be applied to multiple firms within the same sector	[3, 15, 17, 43, 46, 48]
Configurable (adaptable, flexible)	Capability to follow business rule and relevant changes	[3, 15, 17, 26, 42, 43, 46, 48]
Cross-enterprise	Span across the enterprise	[3, 42, 49, 50]
Common interface	Same graphical user interface	[3, 48]
Homogenization	Unique data referential	[15, 42, 43, 46]
Real-time	Real-time update and consultation	[15, 26, 43, 46, 49, 50]
Openness/ RDBMS independent	Modularity and portability	[15, 42, 43]
Transversality/Process-oriented	Process-oriented view	[3, 15, 43, 48]
Best practices	Best practices from the field are embedded in the system	[3, 15, 17, 43-46, 48, 49]
Simulation	Business processes can be simulated	[42, 43]
Substantial advancement	Supports decision making (free data extraction mechanism)	[24]
Technical advancement	Technology does not hinder further development of system	[24]
Safety and Security	Security of information resources and protect IT investment	[24]
Compliance with regulation	Compliant with the law force of the region	[24]

In terms of framework of ERP Systems, there are four emerging topics of ERP system framework based on its implementation [51-54], evaluation [55], development [56] and general [6, 23]. We have excluded sector specific ERP frameworks such as frameworks for small and medium size enterprise (SME) and higher education institutes [9, 55, 57, 58]. From the perspective of this research, only the general framework is relevant. Møller [23] study developed a conceptual framework for ERP II which includes four layers to present what ERP system are constitute of. The four layers are foundation, process, analytical and portal. This model was based on a generic map and to understand the taxonomy of corporate enterprise system. This model is proposed for analysis of completeness of ERP II vision in an enterprise and to analyze the product functionality from an ERP vendor. Marnewick [6] study developed a conceptual model for ERP system linking it with the 4Ps marketing model with the aim to simplify the explanation of ERP in an understandable format for the people. The four components that are included in this model were customer mindset, software, change management and process flow.

2.1. Identification of Gaps

Earlier literature searches show that researchers have extensively explored various aspects of ERP systems, including advanced technology, tier classifications based on specific factors, transformation models, and development taxonomies. However, it appears that no studies have differentiated between the two interpretations of ERP systems within organizational software architecture, as highlighted in section 1.1. This distinction underscores the uniqueness of our study. Additionally, while researchers have extensively documented ERP system characteristics, none have specifically investigated these traits within the software architecture of ERP systems implemented in organizational contexts. To the best of our knowledge, existing literature lacks frameworks that integrate organizational software architecture with ERP characteristics, thereby setting our research apart.

3. Research Methodology

The research methodology followed in this research is design science research (DSR) as it is aligned with the field of information system in terms of proposing a solution to a problem in the academic or professional context. This unique methodology would assist a researcher to create knowledge through the design of an artefact and then introduce it in the environment as a prescribed solution to a particular problem. Design science research method was first introduced by Herbert Simon in 1969. It is crucial to have a methodology in information system research that supports creating innovative artefacts to solve real-world problems [59]. There are four general outcomes of DSR; an artefact in the form of either construct, model, method, or instantiations [60]. The outcome of this DSR research is a model i.e., framework [61]. For this research paper, Peffers, Tuunanen, Rothenberger and Chatterjee [61] process model has been utilized, as shown in Fig. 1. The reason for choosing this model is because it proposes a separate "*demonstration*" step, which is very important to explain the framework to the community of practice.

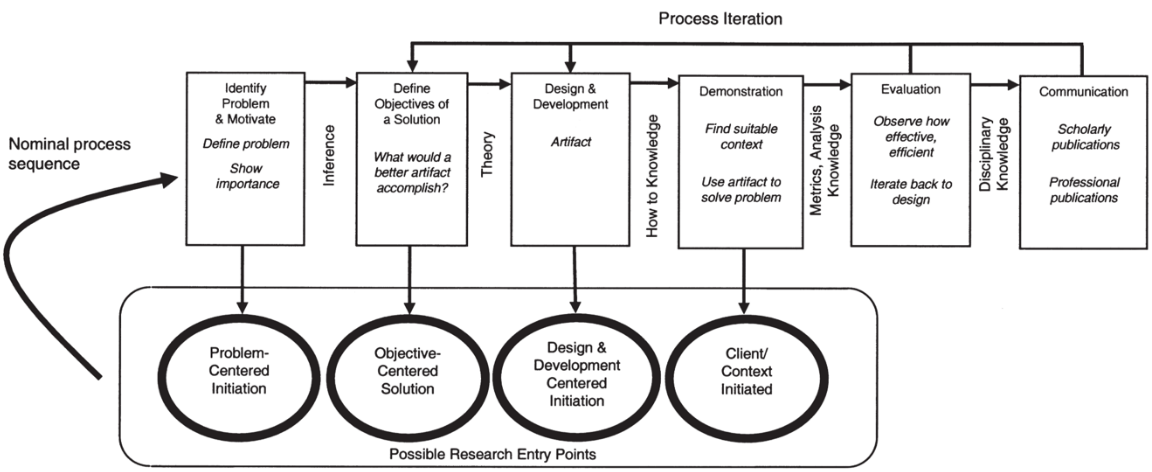


Fig. 1. DSR Process Model, Peffers, Tuunanen, Rothenberger and Chatterjee [61]

The literature also emphasizes that the focus of DSR is not only to develop the artefact but to demonstrate that the artefact can be effectively used to solve real problems [62]. According to the Peffers, Tuunanen, Rothenberger and Chatterjee [61], the DSR process is composed of six steps, and there is a possibility for a research entry point at different steps of the model. Since the identification of the problem and objective of the solution have already been covered in the early sections (1 and 2) of this research, in the subsequent sections, we will focus on designing and developing the framework, demonstration/evaluation using a case study and communication.

4. Proposed Framework

This research proposes a framework in a form of a continuum. A *continuum* is defined as "*something that changes in character gradually or in very slight stages without any clear dividing points*" [63]. According to our proposed framework, there are four categories of ERP systems based on how they are aligned with other systems within an organizational software architecture and therefore distinct in their characteristics. The four categories are: silo systems or no ERP, partial ERP, significant ERP, and total ERP. Fig. 2 illustrates the four categories from the system and database perspective of organizational software architecture.

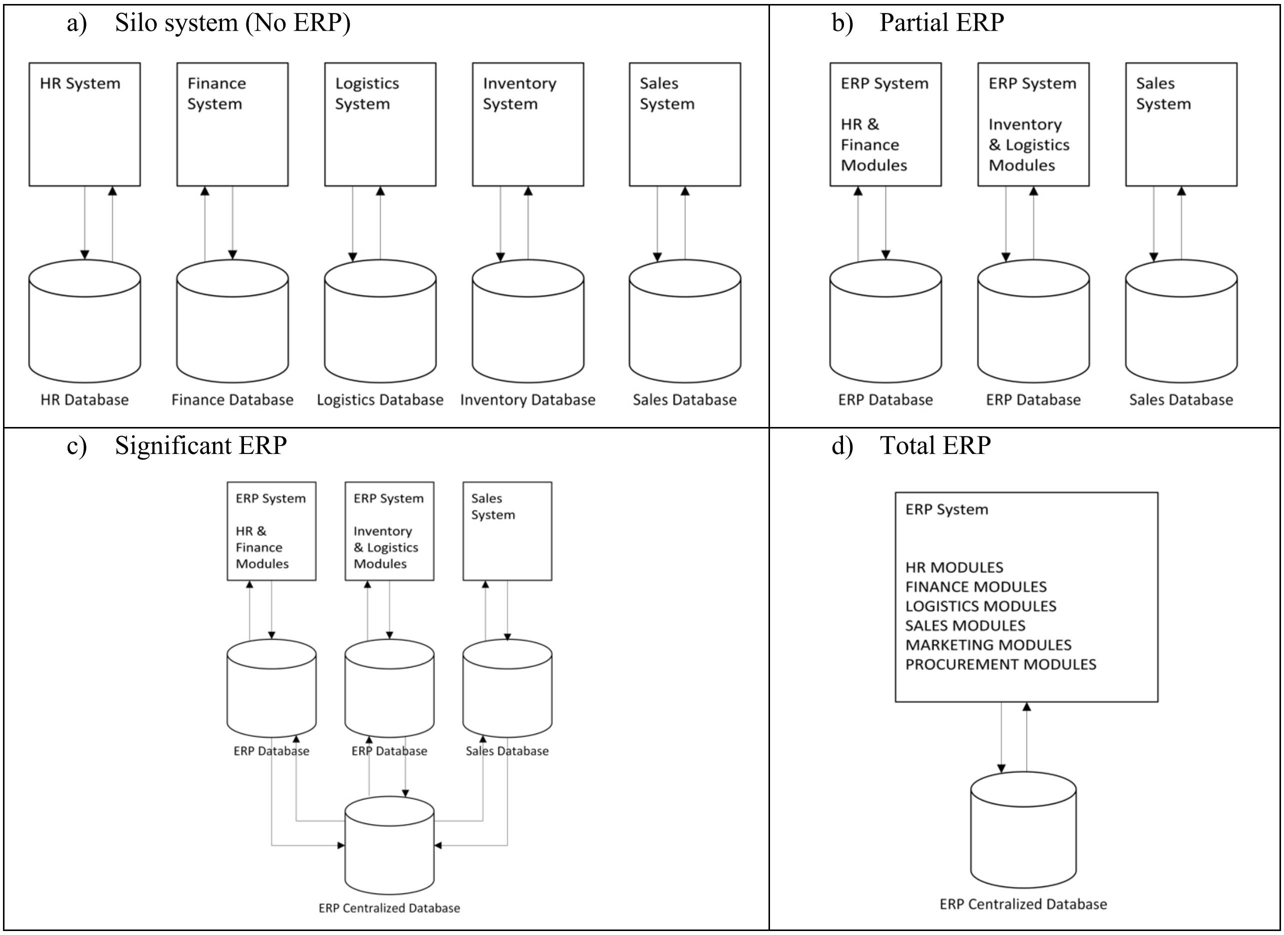


Fig. 2: Categories of ERP System within the organization software architecture, a) Silo, b) Partial ERP, c) Significant ERP, d) Total ERP.

The explanation of each of these categories are provided below:

a) **Silo Systems: Silo system (No ERP)**: In this type of software architecture, each department uses its own information system, which is illustrated as a square box in Fig. 2a. Fig. 2a is a scenario-based illustration showing an organization with five departments and each department has it designated information system and database. The arrows show the communication from the system to the database and vice versa. There can be several reasons for this set up. For instance, it can be seen in start-ups, small-scale ventures, or non-conventional businesses. In this architecture, the different information systems have separate interfaces. If a user has a hybrid role in the organization that requires access to more than one information system, they will need to log in separately for each system.

b) **Partial ERP:** In this type of software architecture, the organization has several departments, and there must be at least one shared system, i.e., an ERP, among some departments. In some instances, organizations use two ERP systems. For example, Fig. 2b illustrates a scenario where one ERP system is used for the HR and finance departments, and the other ERP system is used for the logistics and inventory department. While the sales system is still separate from the rest of the systems. Since there are some shared aspects of the ERP system, it is regarded as a Partial ERP. There can be several reasons for this setup. For instance, the organization did not have a single ERP system that fully met all their business requirements or chose to use multiple systems for differentiation/competition reasons. In this architecture, the ERP systems used between the shared departments generally have similar interfaces, but there can be instances where the user interface is different.

c) **Significant ERP:** In this type of software architecture, the organization has several departments, and there must be at least one ERP system that encompasses most of the functionalities required by the organization. In some instances, organizations might use two ERP systems (as in the previous case) and other silo systems, but all systems are integrated in some manner. For example, Fig. 2c illustrates a scenario where one ERP system is used for the HR and finance departments, another ERP system is used for the logistics and inventory department, and a separate system is used for the sales department. All departmental databases are integrated using a centralized database. Since most of the organization's departments are integrated through technical tools such as a centralized database or API (Application Programming Interface), this setup is regarded as a Significant ERP. The reasons for using this setup can vary, but they can be similar to those for a partial ERP setup. In this architecture, the shared information systems generally have similar interfaces, and it is very rare to use different user interfaces. However, it is very challenging to connect all these separate systems because the programming languages and backends used to develop these software systems can be different and incompatible. There are instances where the integrated tools work in batch processing and update overnight, so communication between departments may not be in real-time.

d) **Total ERP:** In this type of software architecture, the organization has several departments, and there must be at least one ERP system that encompasses almost all of the functionalities required by the organization. In some instances, the organization might use one silo system along with the main ERP system, but the functionality of that silo system should be unique for reasons such as a building management system that controls the temperature of the building or an email management system that runs emails for the organization and does not require integration from a business perspective. Fig. 2d illustrates a scenario where there is only one ERP system with one database and one interface, integrating all departments of the organization in a modular approach, this setup is regarded as a Total ERP. In this setup, a person who has a hybrid role in the organization does not require different logins but can easily access the functionalities needed to perform their job. Since all the main departments are in one location, management can easily obtain interoperable reports from the departments without much effort.

While Fig. 2 visually illustrates the different categories of ERP systems from a software architecture perspective, Table 2 shows the framework, i.e., the alignment of the different ERP software architectures along with their characteristics. In Table 2, the four categories of ERP systems based on sixteen characteristics can be seen. The proposed framework works as a continuum, incorporating ERP characteristics starting from no ERP and leading to a total ERP system in organizations. The continuum uses the ERP definition provided by [3, 9, 10, 12-16, 56, 64-72] and ERP characteristics provided by [3, 15, 17, 24, 26, 40, 42-46, 48-50] in one tabular format. On the top of the continuum, the number of systems based on the two interpretation of ERP system definition can be seen as either "*Multiple*" or "*Single*". The categories of ERP based on software architecture have been indicated horizontally as Silo or No ERP, Partial ERP, Significant ERP and Total ERP. The characteristics of the ERP are indicated vertically on the left-hand side, whereas the description of the characteristics for each ERP category is indicated in its respective cell.

Table 2. Continuum Incorporating ERP Characteristics

ERP Software Architecture	**Multiple Systems**	**Multiple Systems**	**Multiple Systems**	**Single System (All-Inclusive)**
ERP Category ⇒ **ERP Characteristics ⇓**	**Silo or No ERP**	**Partial ERP**	**Significant ERP**	**Total ERP**
Integrated	No integration	Integration between some functions (core business not integrated with the resource base modules, i.e., HR and Finance)	Integration between significant function (core business with resource base modules, i.e., HR and Finance)	Integration between all functions
Modular	Systems are separate	At least one system has some modules. For example, HR and Finance are integrated in a modular form in one system.	At least one system has most modules. For example, HR, finance and CRM, procurement and asset are integrated in a modular form in one system.	Almost all of the modules are incorporated in one system.
Generic	A single solution cannot be applied to multiple firms within the same sector	A single solution can be applied to multiple firms within the same sector with significant configuration	A single solution can be applied to multiple firms within the same sector with limited configuration	A single solution can be applied to multiple firms within the same sector without any configuration
Configurable (adaptable, flexible)	Not flexible to follow new business rules. Change in business rules meaning change the system	Not flexible to follow new business rules. Change in business rules meaning significant changes to the system	Flexible to follow new business rules. Change in business rules meaning minimal changes to the system	Easily changeable to follow new business rules
Cross-enterprise	Data is not shared cross the enterprise	Data from systems is shared in few departments	Data from systems is shared in most departments	Data from system is shared cross the enterprise
Common interface	Various interface for each function	Some departments have the same interface	Most departments have a common interface	All department have the same interface
Homogenization	Different data definition in different systems	Processes share the same data definition in few application modules	Processes share the same data definition in most application modules	Processes share the same data definition in all application modules
Real-time	Does not communicate at all	Communicates but require Application Programming Interface (API)	Communicates in real-time and/or require limited APIs	Communicates in real time/ do not require APIs
Openness/ RDBMS independent	Not applicable as systems are separate	Any module added or removed from the system highly affect other modules	Any module added or removed from the system partially affect other modules	Any module added or removed from the system does not affecting the other modules.
Transversality/Process-oriented	Does not have process-oriented view	Have process-oriented view in few systems	Have process-oriented view in most systems	Have process-oriented view in all systems
Best practices	System does not imbed best practices in the field	System imbeds few best practices in the field	System imbeds most best practices in the field	System imbeds all best practices in the field
Simulation	Business processes cannot be simulated	Few business processes can be simulated	Most business processes can be simulated	All business processes can be simulated

Substantial advancement	Data extraction mechanism to support decision-making is challenging	Data extraction mechanism to support decision-making is accessible but requires high effort/investment	Data extraction mechanism to support decision-making is accessible but requires some effort/investment	Data extraction mechanism to support decision-making is easily accessible
Technical advancement	Technology hinders further development of system	Technology does not hinder further development of system but requires high effort/investment	Technology does not hinder further development of system but requires some effort/investment	Technology does not hinder further development of system
Safety and Security	Requires high effort to ensure safety and security for separate systems	Requires high effort to ensure safety and security for different systems	Requires some effort to ensure safety and security for different systems	Requires low effort to ensure safety and security for the system
Compliance with regulation	Requires high effort to be monitored for compliance with regulations	Requires high effort to be monitored for compliance with regulations	Requires some effort to be monitored for compliance with regulations	Requires low effort to be monitored for compliance with regulations

Using this continuum, academics and practitioners can indicate which category their ERP system software architecture falls into, depending on different ERP characteristics such as integration, modularity, generality, configurability, cross-enterprise capability, interface design, homogenization, real-time capability, openness, transversality, adherence to best practices, simulation, substantial advancement, technical advancement, safety and security, and compliance with regulations. It is also acknowledged that integration is the most important characteristic, as other characteristics will be highly dependent on it. We believe that this continuum is essential for academics and practitioners to categorize different software architectures that implement ERP systems, identify where they fit on the continuum, and assess how many ERP system characteristics they embody to maximize efficiency and effectiveness. It can be inferred from the continuum that the more an organization's system structure leans towards the right side of the continuum, the more efficient and effective it can become. The way to use this continuum is subjective, but it provides a clear idea to academics and practitioners that even though an organization is using an ERP system, it does not guarantee maximum efficiency and effectiveness unless they can demonstrate a higher degree of ERP characteristics. The degree of ERP system characteristics increases as the system moves through the continuum from left to right. If the system architecture is placed on the right-hand side, it demonstrates that the organization has a total ERP system, possesses most characteristics of an ERP system, and is anticipated to be more efficient and effective.

5. Application of Proposed Framework (Case Study)

In the above section, we have designed and developed a framework for understanding ERP based for the problem encountered in the literature in understanding the term "*ERP system*". Now we will proceed to the next step of demonstration and evaluation in the Design Science Research process model. We will not formally evaluate the framework because it has not been widely used. The literature also suggest that demonstration is an alternative way to evaluate an artefact [73, 74]. So, we will use a case study approach as a guidance to demonstrate how to apply this framework in practical scenarios. The case study we will use is of a vocational education training provider in Saudi Arabia who used an in-house developed ERP system called StallionERP for management of the colleges. The management of this provider has indicated that the StallionERP system covers almost all of their business requirements. Therefore, before the evaluation, we assume it would fit into the total ERP system category.

5.1. The Case Study

The vocational education training provider operated in Saudi Arabia with the name The Oxford Partnership (TOP). It operated four colleges in different geographical location for over a period of six years from 2014 to 2020.

TOP followed a shared services model in their organizational structure and had eight departments namely Data and Examinations, Human Resources, Finance, IT, marketing, admissions, facilities, and employer engagement. Initially in late 2014, the colleges had limited information systems in several departments like MIS and admissions office but operated in silo. If we analyse the ERP category based on the continuum in 2014, it is clear that it would fall under the Silo or No ERP category. We have demonstrated this using the continuum in Table 3 using the $ sign to indicate the ERP system category based on its characteristics for TOP in 2014. In 2016, TOP took the initiative to develop an all-inclusive ERP system aiming to have a single system with all the required functionalities. Within a period of four years, TOP implemented and used the StallionERP system in most of its departments. Using the continuum for ERP category, we have evaluated the ERP system category for TOP in 2020 which is indicated by a * in Table 3.

Table 3. Evaluating the category of ERP system in the case of TOP in 2014 and 2020

Systems based on two definitions	**Multiple Systems**	**Multiple Systems**	**Multiple Systems**	**Single System (All-Inclusive)**
ERP Category ⇒ **ERP Characteristics ⇓**	**Silo or No ERP**	**Partial ERP**	**Significant ERP**	**Total ERP**
Integrated	$		*	
Modular	$			*
Generic	$	*		
Configurable (adaptable, flexible)	$	*		
Cross-enterprise	$		*	
Common interface	$			*
Homogenization	$			*
Real-time	$			*
Openness/ RDBMS independent	$		*	
Transversality/Process-oriented	$		*	
Best practices	$		*	
Simulation	$		*	
Substantial advancement	$			*
Technical advancement	$			*
Safety and Security	$		*	
Compliance with regulation	$		*	

From the total of sixteen characteristics, in 2014, TOP scored all the sixteen characteristics in the No ERP category indicating the absence of ERP system. In 2020, from sixteen categories, TOP scored eight in the significant ERP category and six in the total ERP category. This implies that TOP has integrated most of its departments with different modules incorporated into a single system. The integration is not deemed to be "*full*" because TOP would require its system to be accessible for students, parents, and suppliers to interchange data for it to be in the total ERP category. The solution StallionERP provided is generic but cannot be used by all education institutes, hence the "*generic*" characteristics is indicated to be of "*partial ERP*". Depending on the business rule, some can mean that there is a major change required to the system. Since it is a single system, the interface for all the departments is the same, data definitions are the same, and the system communicates in real time. For instance, if a teacher marks a student attendance as "*present*" in the system, the MIS can run the report at the same time to check the attendance percentage of the students. Moreover, the technology does not hinder the system development and the data can be readily available to support decision making as StallionERP had a key performance indicator module embedded.

Furthermore, if any additional data is required, no effort is required to extract it from the database with interoperable data. Data sharing was in most of the departments but there were some departments that data was difficult to obtain such as in the case of facilities management, the system did not have a comprehensive field. Those data were managed externally. If there was any module that was required to be removed, there was a need to check data dependencies to ensure the data is not used elsewhere. Lastly, since the development was in-house, the best practice, simulation, safety, security, and compliance with regulation required some effort and external consultation to maintain, therefore they are scored to be at significant ERP category. Overall, one can say that TOP's software architecture is regarded as good (in the significant ERP category) and it's on its way to be in the total ERP category. As discussed above, StallionERP has one constraint: this system is not accessible to students or parents for everyday communications. Whenever the students need to complete an assessment or a survey, a link is sent to their email for completion, and the data is collected by StallionERP. However, students and parents do not have login credentials to access the system. For this reason, it cannot be regarded as a total ERP system. It is true that StallionERP has helped TOP achieve higher levels of efficiency and effectiveness [11], but there is always room for improvement. In this case, developing a function to allow parents and students to access the system and monitor the student data in real time would be a beneficial enhancement. Appendix A demonstrates a high-level Use-Case diagram for the software architecture used by TOP. Use case diagrams are utilized to model the functionality of a system by illustrating the interactions between the system and its actors [75]. The goal of presenting this use case diagram is to depict the context of ERP systems. Appendix A shows that there is one ERP system called StallionERP, which is the main system that includes all the functionalities required by the business. There are also other systems that do not need to be integrated through the business requirements, such as the Building Management System (BMS), the email system, and the Learning Management System (LMS), i.e., Canvas. Appendix B shows a snapshot from the system listing all the modules from the system admin perspective.

The final step in the Design Science Research process model is communication. In this last step of the DSR process, the results are consolidated in the form of a final report to be communicated to different stakeholders and communities of practice [76]. An attempt to publish this research paper is part of the communication step in DSR.

6. Research Implication and Conclusion

The literature review revealed that the term "*ERP system*" was widely used by academics and practitioners to designate integrated systems, but not all ERP system implementations imply full integration, as this depends on the software architecture of the organization that implemented the ERP system. Using the two interpretations of the term ERP provided in Section 1.1, the researchers used design science research methodology to investigate the issue of inconsistency in understanding the term "*ERP system*" and provided a solution to understand ERP systems using their characteristics and assessing the organizational software architecture based on these characteristics. Since not all ERP system implementations are the same, as they depend on the individual organization's architecture, the research proposed a framework in the form of a continuum that categorizes ERP systems used by organizations into four categories: Silo, Partial ERP, Significant ERP, and Total ERP. The framework was presented visually using diagrams and scenarios. Moreover, a tabular format that aligns the different ERP software architectures with ERP characteristics was also presented. The research concluded with a case study demonstrating how to use the framework.

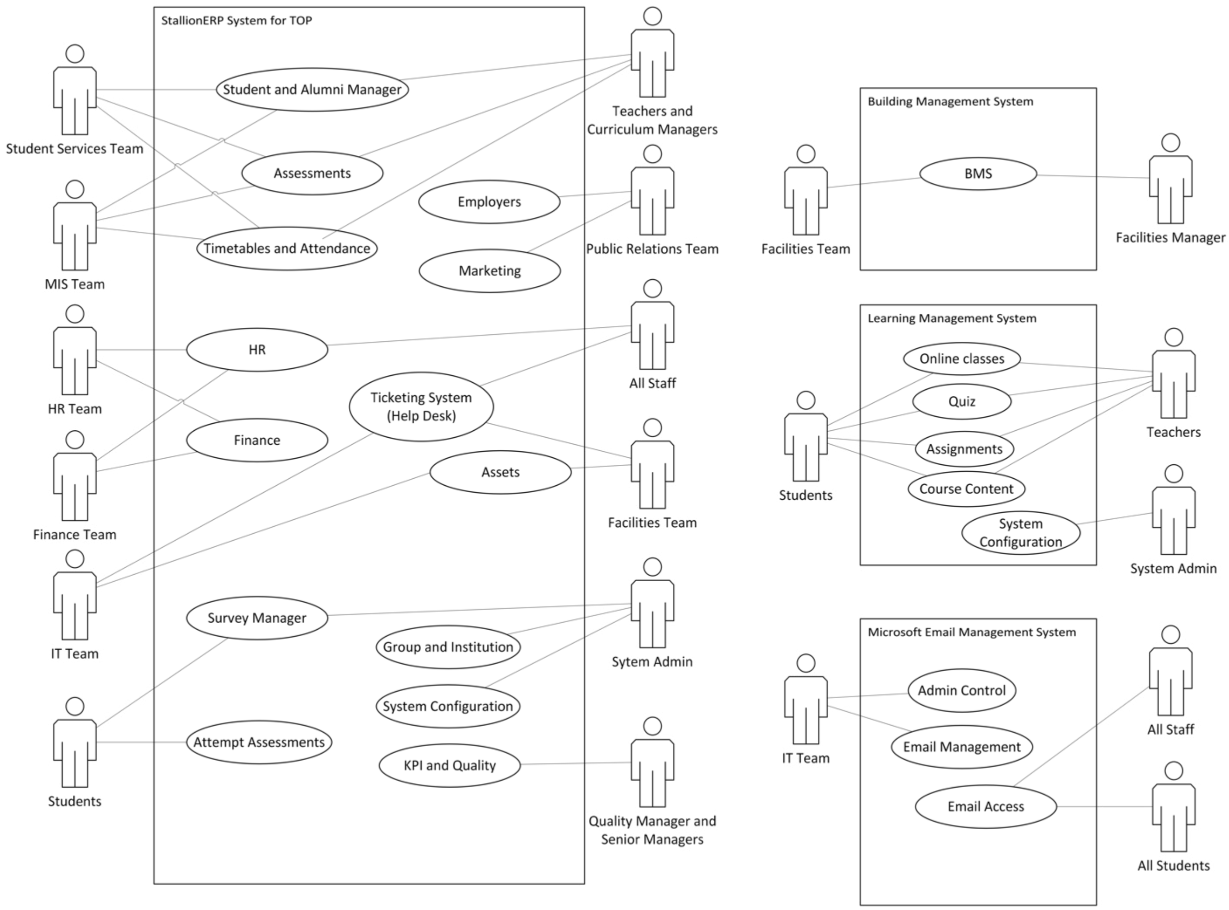
Our research contributes to the literature by providing a nuanced understanding of ERP systems. Unlike previous studies that treat ERP systems as somehow uniformly beneficial, we highlight the variability in their effectiveness based on organizational software architecture. This study extends the theoretical framework by categorizing ERP implementations into Silo, Partial ERP, Significant ERP, and Total ERP. Practitioners can utilize our findings to better assess and plan their ERP implementations. Organizations should carefully evaluate their existing software architecture to determine their current ERP category and what category they aim to achieve as part of their strategic planning. As it is discussed above, the more an organization is positioned on the right side of the continuum, the higher its efficiency and effectiveness. Our framework can guide businesses in optimizing their ERP deployments, ensuring better integration and functionality across departments. Future researchers can use this framework to investigate the causes of ERP system failures, which may be rooted in their incompatibility with the organizational software architecture, resulting in systems leaning more towards the Partial ERP category than achieving complete integration i.e., total ERP. Additionally, further studies could refine our framework and explore the role of emerging technologies in ERP systems integration without the need for having one total ERP system through the use of Service-Oriented Architecture (SOA).

Overall, our research provides valuable insights into the varied effectiveness of ERP systems, emphasizing the critical role of organizational software architecture. By applying our continuum framework, both academics and practitioners can better understand and enhance ERP implementations, ultimately driving greater efficiency and integration within organizations.

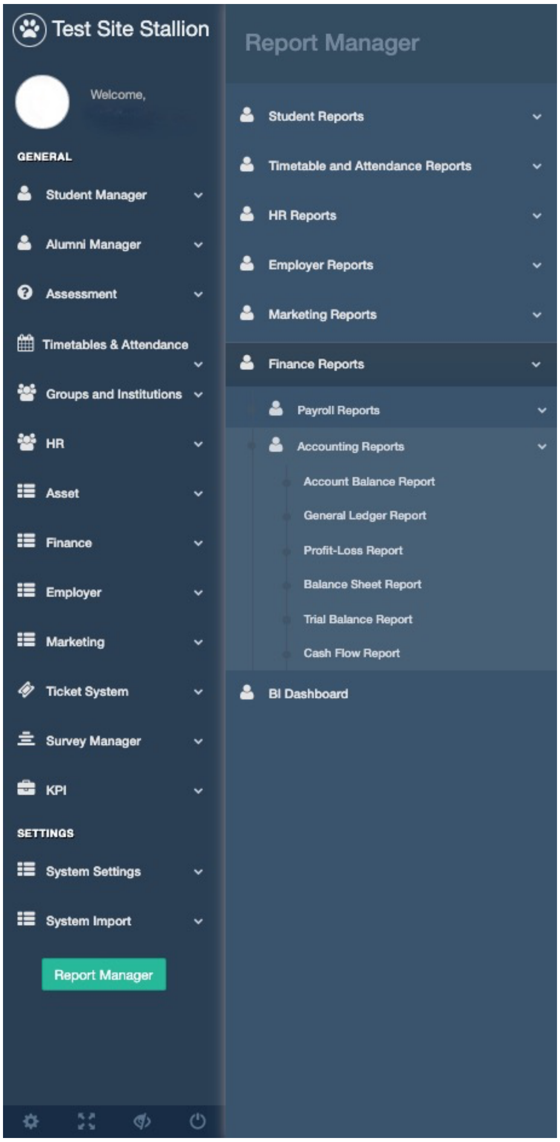
7. Limitation and Future Considerations

According to Theofanidis and Fountouki [77] research limitations are weaknesses beyond the researcher's control. They suggested that reporting the limitation of a study improves the quality of findings and interpretation of the evidence presented. One of the limitations of this study is that it the artefact or framework developed could not be evaluated as it is too early to evaluate. We have only used the step of demonstration as an alternative way to evaluate an artefact as suggested by the literature [73, 74]. We suggest the future researchers to use and evaluate this framework from their perspective. Another limitation is that this study was conducted from an information system perspective only and not been studied from system engineering, computer science or business/management perspectives. Lastly, the limitation is that this study was conducted qualitatively, there is a chance for future researchers to create a quantitative measurement to categories ERP system based on the framework provided.

Appendix A. High Level Use Case Diagram for StallionERP system used by The Oxford Partnership



Appendix B. Snapshot from the System Admin account of StallionERP system showing modules of different departments



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