Future ERP Systems: A Research Agenda

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Abstract: This paper presents a research agenda on the current generation of ERP systems which was developed based on a literature review on current problems of ERP systems. The problems are presented following the ERP life cycle. In the next step, the identified problems are mapped on a reference architecture model of ERP systems that is an extension of the three-tier architecture model that is widely used in practice. The research agenda is structured according to the reference architecture model and addresses the problems identified regarding data, infrastructure, adaptation, processes, and user interface layer.

1 INTRODUCTION

The digital transformation as well as the further development of existing products and services set new requirements to the dominating class of enterprise systems in companies, the ERP systems. These requirements stem partly from problems that are related to the architecture of ERP systems, the way the systems are implemented which is tightly related to the aspect and degree of customization.

Except for challenges related to the systems themselves, the changing business landscape poses new requirements on ERP systems. For instance, the emergence of the Industrial Internet of things (IIoT) allows processes and decision-making to be supported by data that was gathered throughout operation (Lazarev and Nekrasov 2017; Bragalia et al. 2019).

So far, research on ERP systems to a great extent focussed on the implementation and post-implementation phase and corresponding critical success factors (e.g. Mahraz et al., 2020; Poluektova et al., 2018; Zare Ravasan and Mansouri, 2016). While this lifecycle-oriented perspective is of great importance for practice, problems related to the architectural design of current-generation ERP systems are of minor importance in previous considerations. As such, the problems of ERP are not addressed holistically. This leads to the issue that the system design, which might be the root of many problems during system implementation and operation, may not be attributed to the relatively stable architecture of ERP systems.

By means of a literature review, problems with the current ERP system generation were systematically identified and mapped to a reference architecture model of ERP systems. Related findings are integrated into a research agenda. The integration of the lifecycle and architecture perspective may guide the conceptualization of the next-generation enterprise systems.

The paper is structured in four sections. The following selection introduces the architectural framework and attributes the problems identified in the literature. Section three presents the research agenda, while section four concludes the paper.

2 PROBLEMS OF CURRENT ERP SYSTEMS

The research agenda on the future ERP systems is centered around a reference architecture model of ERP systems. In contrast to previous approaches, the idea is to systematically group the identified issues according to the different levels of systems architecture. Thereby, this approach allows to attribute related challenges to the respective research domains and develop solutions accordingly. Finally, the integration of findings allows fostering the discussion on the future generation of ERP systems in terms of architecture.

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2.1 Theoretical Background

The reference architecture model by Andresen and Gronau (2005) that is considered in this article is an extension of the three-tier architecture that is widely used in practice. The three-tier architecture followed the generation of two-tier ERP systems, a simple client-server division (Bahssas et al., 2015). For a three-tier ERP architecture, more layers are specified. Those are presentation or user interface, application, and database (Bahssas et al., 2015; Qin and Wei, 2013). The user *interface or presentation layer* forms the connecting piece between the system and the user. The dialog triggered by the user via the user interface is admitted at this layer. The *application or functionality layer* combines the central algorithms of the software. Software components are structured on this layer and resources and transactions are executed and managed here. This includes the processing of the data, which is read from and written to the database. On the *database layer*, manipulations are made to the stored data. The data is managed in a database system, which is usually relational in the current generation of ERP systems (Plattner 2009).

The extended reference architecture model was introduced by Andresen and Gronau (2005) to address the lack of adaptability that comes along with the traditional design of ERP systems (see Figure 1). According to the authors, an ERP systems architecture (should) specify additional levels besides the layers mentioned. These additional layers are the control layer, located between the presentation and functionality layer, the infrastructure layer which is below the database layer, and the adaptation layer which is a cross-section layer. The *control layer* is where business processes should be monitored, and internal consistency is ensured. The control layer should provide the possibility to model business processes with a specific modeling language. Depending on the architecture of the respective ERP systems, processes are mapped via workflow engines, which are part of the application layer. The *infrastructure layer* includes decisions concerning distribution and topology. The cross-section to all layers is the *adaptation layer* which covers all adaptations that were implemented individually for companies (ibid.).

2.2 Findings from Literature

To gain an understanding of the current state of research on problems rooted in the selection, implementation, and lifecycle of ERP systems as well as its design and architecture a literature review was conducted. For this purpose, the database Web of Science was queried. Keywords included “ERP” OR “Enterprise Resource Planning” AND “problems” OR “issues”. Since the focus of the review lied in current literature the time span was limited to the past five years (2016 - 2020). Moreover, central influential articles were identified through backward reference research. The literature review was intended to be representative and therefore to serve as a basis for developing a research agenda (Cooper 1988). Completeness was not aimed at.

In the following, the literature which identified problems with ERP systems or tackled these is presented. The problems are centered according to the problem domains and phases.

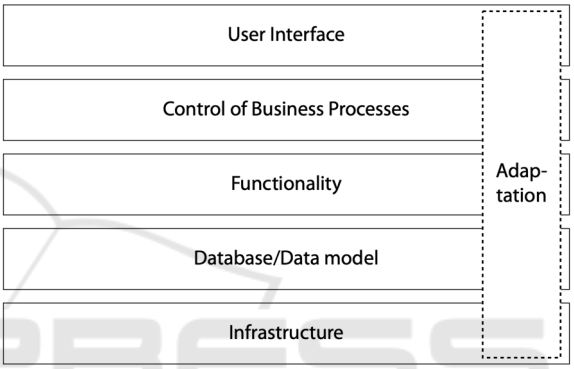

Figure 1: Enterprise System architecture layers according to Andresen and Gronau (2005).

2.2.1 Problems Related to Customization

Although ERP systems are standard software packages, also known as commercial off-the-shelf products (COTS), some customization always becomes necessary to meet the functional and process requirements of the implementing organization. This topic is therefore of great interest in the research community (Daneva, 2014; Light, 2005; Parthasarathy and Sharma, 2017; Zare Ravasan and Mansouri, 2016). Customizations can be manifold and the widely used terminology that distinguishes between configuration and modification is not sufficient to estimate the associated efforts required for implementation and maintenance (Brehm et al., 2001). To customize an ERP system can be problematic in various ways because it raises the complexity of the software itself and the implementation project. With customization the risk for deployment and upgrade difficulties increases. Heavy customization can even lead to project failure (ibid.). Database and source code customization in particular can cause issues with regards to software quality (Parthasarathy and Sharma, 2017).

2.2.2 Problems Related to ERP Selection

ERP selection is comprehensively researched as a complex multi-criteria decision-making problem to find the ERP system that matches the processes of an organization best without the need for modifications in terms of customization efforts (Ayağ and Yücekaya, 2019; Hinduja and Pandey, 2019). Naturally, quite some research deals with misfits of ERP systems after selection which is a common problem in practice (Wu et al., 2007). The increasing use of cloud computing also influences the ERP market. Companies that select a new ERP system are faced with the decision of whether to operate it on-premise or in the cloud. Recent research is devoted in part only to cloud ERP systems and corresponding implications and risks like functionality fit and customization, data migration, organizational change, reliability as well as data security and integrity (Hinduja and Pandey, 2019; Saa et al., 2017; Şener et al., 2016; Sørheller et al., 2018).

2.2.3 Problems Related to ERP Implementation

After a successful selection of an ERP system, the next challenge for companies constitutes the implementation phase which can be even more complex, difficult, and risky, especially for SMEs (Leu and Lee, 2017; Poluektova et al., 2018). Factors that lead to failure include among others: heavy customization efforts, poor business process reengineering, poor consultant quality, and the lack of top management support (ibid.).

2.2.4 Problems Related to ERP Usage

After implementation, in the usage phase, some companies have difficulties in realizing the benefits of implementing an ERP system. This is because companies lack the competencies to define benefits to be expected before implementation and to monitor success and failure (Anaya, 2019). Key users can play an important role as knowledge managers for the realization of benefits in this phase (Maas et al., 2016). ERP upgrading being a typical maintenance process in the usage phase is considered just as a complex problem as ERP selection (Goman and Koch, 2018). It includes similar steps like requirements engineering, the evaluation of options, and the identification of dependencies (ibid.). Related to this is a challenge for companies to find the right time for a systems' switch because the status of alignment between business and system often is unclear over time despite customization decision in the early phase of implementation (Huang and Yokota, 2019).

2.2.5 Further Problems

Other problems that are discussed in the literature concerning ERP systems are (master) data quality issues (Zong et al., 2017) and master data management (Schäffer and Leyh 2016). Other research focuses on poor usability that is hindering productivity gains (Babaian et al., 2017) and interoperability and integration problems that can be due to semantic interoperability (Badr et al., 2016) and environmental, technical, managerial as well as organizational aspects (Banaeianjahromi et al., 2016).

Considering the specifics of the manufacturing industry, further problems occur. For instance, ERP systems seem to not support the monitoring of production processes sufficiently because they only provide synthetic information about the inputs and outputs of processes. That makes it necessary to close the gap between ERP and production management systems (Krótkiewicz et al., 2019). The increasing importance of industry 4.0 that entails among others more available information brings new requirements for ERP systems that are not met in practice yet (Braglia et al., 2019; Lazarev and Nekrasov, 2017) like higher security standards (Elkhawas and Azer, 2018).

2.3 Problem Mapping

Apart from the lifecycle-oriented consideration of ERP systems, which dominates previous literature, most problems identified in the literature can be mapped to the layers of the reference model (Table 1). The following overview is filtered for problems that can be attributed to a specific layer of ERP systems. This focus allows to further develop the architecture of enterprise systems which may help to resolve the origin of potential issues on the architectural level of enterprise systems.

As such aspects that solely focus the ERP project as such are not considered for the research agenda on the architectural issues of the current ERP systems generation.

Table 1 shows that the problems identified in the literature mapped with the architecture reference model (see section 2.1).

Table 1: Problems identified in literature per layer.

Problem	References	U	P	F	D	I	A
Data quality	Zong et al. (2017)			x	x		
Poor usability	Babaian et al. (2017)	x					
Integration and interoperability	Badr et al. (2016) Banaeianjahromi et al. (2016)						x
Security standards	Elkhawas and Azer (2018)			x	x	x	
Monitoring requirements	Krótkiewicz (2019)			x	x	x	
Levels of customization	Brehm, Heinzel and Markus (2001)			x	x		
Requirements from Industry 4.0	Bragalia et al. (2019) Lazarev and Nekrasov (2017)			x	x	x	
Cloud ERP	Hinduja and Pandey (2019) Sorheller et al. (2018) Saa et al. (2017) Şener et al (2016)		x	x	x	x	
Software quality issues	Parthasarathy and Sharma (2017)			x	x		
Customization requirements	Ibrahim et al. (2017) Daneva (2014) Ravasan and Mansouri (2016) Light (2001)						x
Amount		***1***	***1***	***7***	***7***	***4***	***2***

3 RESEARCH AGENDA

While previous literature focussed on specific phases of the ERP lifecycle, we call for a consideration of the architectural layers of modular ERP systems to resolve prevailing challenges. Assuming that many of the existing challenges are rooted in the architectural foundations of ERP systems, system providers are interested in how ERP systems can be further advanced to fulfil the newer requirements of customers.

This very first analysis of the problems of the current ERP system generation showed that the most pressing problems occur around databases and data models. The equal number of problems are related to the functional layer. Next in line are problems related to the infrastructure layer followed by the adaptation layer. Fewer problems occur around user interfaces and the storage and the control layer, which is not even available for all existing ERP systems.

3.1 User Interface

The user interface of ERP systems lags behind other system categories concerning the adaptability to the requirements of individual users. In this regard, future developments may focus on the needs for special user groups, such as young and old users or beginners and advanced users. So far, the individualization of enterprise systems is commonly bound to the use of favourites and the like. Holistic concepts focusing on adoption are rarely available. Nonetheless, the importance of usability for ERP systems for acceptance and project success has been highlighted (Masa'deh et al., 2019).

With the increasing possibilities and demands towards mobile operation, the group of ERP systems may add responsive designs and web-based approaches in their portfolio. While many systems still rely on rich client architectures, the newer generation of enterprise systems focuses on web-based frontends such as HTML5-based approaches which require only a standardized browser environment for operation.

Finally, the group of ERP systems may support newer forms of interaction, that do not only rely on predefined forms. Available technologies in the form of speech recognition may allow for more interactive operation with ERP systems. Providers of ERP systems are well-advised not to develop their own solutions, but to provide specialized domain skills for their systems to combine established technologies with domain particularities.

3.2 Control of Business Processes

Business Processes vary between companies. While some domains such as financial accounting are highly regulated and standardized, operations in domains such as logistics and manufacturing vary between companies. These differences may constitute the competitive advantage of companies (Lengnick-Hall et al. 2004). ERP systems need to support and maintain the competitive advantages of companies. Especially for companies with individually developed software, maintaining their competitive advantage is a major concern when considering the use of standardized software packages, such as ERP systems (Lengnick-Hall et al. 2004).

To support the adaptability of individual enterprise operations, ERP systems should allow for reconfigurable processes. To do so, ERP systems may provide their standard processes as a combination of micro-services that are combined towards business processes using modelling approaches. For this,

standardized notations such as BPMN may contribute to common sense within the respective system category. The approach of "modelling instead of programming" may guide future progress in the domain of ERP systems. More and more system providers add the functionality of workflow designers in their systems. This allows system users to add specialized procedures to existing standard processes. However, especially regarding the core processes in ERP systems, the easy adaptability to specialized conditions is limited.

3.3 Functionality

Concerning the functionality of ERP Systems, different aspects are of interest from an academic and business standpoint. With the emergence of highly specialized software systems, for instance, for logistics and manufacturing as well as customer-related CRM-systems, the question regarding the future role of ERP systems emerges. While from the early generations of ERP systems different business functions were combined, future setups may involve less integrated enterprise systems with additional specialized systems. The ERP then serves as the central point of integration. This also poses requirements regarding the interoperability of ERP systems and their specialized counterparts.

Even though the standardization of ERP systems is a major advantage, a major success factor of system operation is the fulfilment of specialized domain requirements such as in the automotive or health industry. So far, an industry-standard ERP implementation strategy has not been developed in the past (Ali and Miller 2011). In this regard, the right level of standardization and specialization remains an important challenge for system providers. Also, system concepts that allow for generic functionality with domain specialization deserve further attention. With the emergence of software platform architectures, future system generations might also allow for third-party contributions in the form of software modules (e.g., extensions, add-ons) as part of the modular software infrastructures (Tiwana et al. 2010).

3.4 Database / Data Model

Many of the identified issues are related to the data layer and related data models that are to be addressed in future research. The data layer in ERP systems serves as the permanent representation of business transactions. To do so, enterprise systems typically rely on relational database systems. Relational database systems have long been the standard in the enterprise application field (Plattner 2009). However, relational databases recently reveal weaknesses concerning new requirements. Increased data volumes constitute a challenge concerning analytical requests on existing database architectures. From a broader perspective, requests in enterprise systems can be categorized into transactional (OLTP) and analytical (OLAP) processes. While relational databases perform well on transactional processes they do not on complex analytics requests (Plattner 2009). So far weaknesses were usually counteracted with increased resources in terms of hardware and approaches such as in-memory databases. While increased resources allow for faster processing of database requests, they do not address the structural problem of relational databases concerning analytical requests (Meyer et al. 2015). Future research may provide concepts to provide integrated or hybrid data environments that allow for the required performance regarding transactional and analytical requirements.

Enterprise systems and databases in specific are faced with the field of tension between standardization and individualization. With the aim of ERP systems to integrate different products into one coherent data model, they might fail to address the individual specifics of related domains. While for instance, one product might be a food product stemming from a recipe, another product might be a machine being composed of a bill of materials. While standardization provides many advantages concerning the uniform treatment of related products, it might fail to cover the ever-increasing complexity and specialization of products. New forms that allow for a combination of standardization and covering the particularities of products are to be identified in future research.

Databases of ERP systems need to be more adaptive and self-automatized. While many database approaches rely on predefined structures, the potential of recognizing patterns in existing data structures and data entries is not fully realized yet. Master data management for a long has been a challenge of enterprise systems. To improve related issues, corresponding functions can be implemented on the level of the data model. Therefore, findings from related fields such as AI and machine learning are to be adapted to the context of enterprise systems data structure.

With the rising complexity of nowadays system landscapes, interoperability becomes another urgent topic. Not all companies have Enterprise Application Integration (EAI) tools available and ERP system typically offers few possibilities to manage and adapt interfaces to other systems.

3.5 Infrastructure

Concerning the infrastructure layer, three aspects were identified. Modern hardware infrastructures provide enhanced power for processing. For example, new processor architectures allow for massively parallel processing (Wust et al. 2012). Modern enterprise systems should be able to utilize related advantages for their operation. To do so, the software architecture of an ERP system needs to be adapted accordingly. In this regard, future research could analyse the architecture of the systems and asses how far ERP systems currently use related possibilities. Moreover, the conception of architectural archetypes allows deducting design principles for modern systems architecture.

ERP systems as a central software instance in companies should allow for the scalability of related business operations. Scalability is required over the long term, for instance when companies grow over time, as well as in a short period, for instance in times of high transaction volume such as Christmas shopping. Moreover, scalability is required up- and downwards. Future studies might identify which system architectures do well with regard to scalability and develop architectural principles that contribute to ERP system's scalability.

With the emergence of cloud-based software provision and Software as a Service (SaaS) offerings, current and potential ERP users are faced with the question of which is the most suitable type of provision for them (Hinduja and Pandey 2019). While some requirements, as well as regulations, may restrict the use of cloud services, the option may be of interest to many users. In this regard, research and practice are requested to develop decision models that allow for the identification of the ERP provision that best fits their targets.

3.6 Adaptation

The possibilities of adoption in the ERP domain are important for the implementation as well as the operation phase.

During system implementation, the design of ERP systems needs to allow for the adoption of the system as a whole as well as on each layer. For instance, the adoption of the user-experience layer may allow for user-specific needs to enable more effective system usage. Adoption of the business process level involves reconfigurable business processes. In terms of enterprise systems functionality, it might be possible to add extra functionality or include specialized systems. From an overall perspective, ERP systems should balance their power of standardization with the possibilities to support individual companies, their operation, and users.

During the operation stage, systems need to be adaptable to newer circumstances. So far, the implementation of a newer system version still is a common issue in ERP system operation (Barth and Koch, 2019). Related upgrades are often considered extensive projects with many costs involved (ibid.).

4 CONCLUSION

This position paper proposes a research agenda to address problems that exist with the current generation of ERP systems. Recent problems were identified within the literature and presented according to the traditional ERP lifecycle-oriented consideration.

Many of the problems during ERP selection, implementation, and usage can be attributed to the system's design and architecture. As such, the authors call for the consideration of the architecture of enterprise systems as the root of related issues. To do so, existing problems were mapped on a five-layer reference architecture model. By that, future research might be devoted to related issues in more specialized domains rather than a consideration of ERP systems as a whole. Specialized solutions can afterwards be integrated into the overarching systems architecture.

Issues were identified for the infrastructure, database, functional, control of business processes, user interface, and adaptation layer. Indications for further research are given. The research agenda presented might foster the discussion on the future role and architecture of ERP systems.

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