ERP Conceptual Ecology

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Abstract. The technological evolution of recent years has made that information systems frequently adapt to the market realities to fulfill the improvements of the company's organizational processes. In this context, new paradigms, approaches, and concepts were disseminated through the new realities of information systems. This study aims to verify how ERP (Enterprise Resource Planning) has been related to other information systems within its ecosystem. For this purpose, we have reviewed the literature based on 650 publications whose central theme was the ERP. The data were treated through a graphical analysis, inspired by SNA (Social Network Analysis), represented by related ERP concepts. The study results, determine the connection degree between the concepts that emerged with the technological evolution and the ERP, thus representing the ERP interoperability tendencies, over the last years. The study concludes that ERPs have been improving and substantially increasing the conditions of interoperability with other information systems and with new organizational concepts that have emerged through the technological availability. This fact led to a better organizational process's adoption and more organizational performance.

Keywords: ERP · Enterprise Resource Planning · Information systems · Systems integration · SNA · ERP evolution

1 Introduction

Many studies produced by several authors have pointed to ERPs as an essential information system to the service of organizations. Also, new business strategies became mechanisms that generated more challenges for companies and consequently new information systems requirements. These data inputs (internal and external) have been increased business intelligence levels [1], which contributed to a better optimization of the relationship between management processes and processed output, where the ERP was the critical element of an information systems infrastructure that supported the organizational processes [2–4]. This study has as main objective shows that nowadays the ERP ecosystem moves a new paradigm based on intermobility principles that it strongest the relation between the ERP, new organizational needs concepts and other information systems. Thus, with this work, we also want to demonstrate how the ERP accompanied the challenges posed by technological evolution, in the sense of the organization's needs that suggested new system updates or

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even new information systems implementation to guarantee that organizations had aligned with market needs and updated with the last technological trends. To reach the objectives of this study, a review of the literature based on scientific articles on ERP was carried out. The research was done through ACM's digital library (ACM, 2018) between the years 1991 and 2015. We believe that the results presented in this study contribute to a better understanding of the importance of ERP to its ecosystem, namely the degree of relationship of ERP with other systems and other concepts, in IT scope. The structure of this article focuses on five sections, which reflect the development of the work involved in achieving the proposed goal of this research. Section 1 describes the purpose of this work and used methodology. In Sect. 2, the theoretical foundations and concepts related to the ERP ecosystem are systematized through a literature review that filtered the relevant theoretical aspects, needs to the study. Section 4 describes the empirical research. Data was collected by a social network analysis tool, that was used to process the information in the direction of results and study conclusions.

2 Background

2.1 Information System

An organization can be defined as an intentional combination of people and technologies [5] with the purpose of achieving specific objectives. The full organization knowledge reality is fundamental to information systems design that can contribute to the materialization of its mission [6]. The information system can be defined as a sociotechnical entity that, through a set of equipment and logical supports, can perform tasks such as acquisition, transmission, storage, retrieval and data exposure [7]. We understand that this definition is the one that best fits within the scope of computer science and specifically in the interests of this work. The information systems are firmly integrated with the organizations [8], making that practically all organization activities depend on the information systems to ensure their proper functioning [9, 10].

2.2 Enterprise Resource Planning (ERP)

Traditionally, ERP is a solution that integrates business functions into a single system and can be shared across all of the organization [10–12]. An ERP can be defined as an integrated commercial software package that flows through the entire enterprise [12–16] and which are used to gain operational and strategic competitive advantage. A strong ERP market growth is expected in the next 7 years through new paradigms, as the cloud [17] and IOT (internet of the things) ERP facilitate the information and communication flow between different organizational units [18], but only show their real potential, if the ability to integrate with other subsystems is feasible [12, 16, 19–22]. In recent years ERP has incorporated other extensions of business, such as logistics, customer relationship management, information mobility among others, thus becoming increasingly competitive software, in the sense of its completeness needs and market requirements [23].

3 Methodological Approach

This study intended to understand the ERP evolution on the point of view of the integration with other information systems and subsystems. As mentioned above, ERP has emerged as a response to the intense competitiveness of firms in the market, at a time than stock control in industrial management was carried out in a very traditional way, without any control as regards the production needs. It was then possible through these programs to calculate the active material needs, necessary to produce the finished products in a controlled manner, in addition to achieving a global and integrated view of most of the organizations' business processes through ERP [24]. We collected 560 publications from all the authors who published their research work ACM, between 1991 and 2015. The data collection focused only on publications that in keyword list has the word ERP or Enterprise Resource Planning. Next, we collect all the abstracts of those studies, and we made filter mechanisms that were used by development tools (see Fig. 1). The objective was to understand what the most common concepts involved with the word ERP are. Thus, we decide it excludes the ERP word and its synonyms from our selection data. We found 44 keywords that which were shown to be more common in our data collected universe. The information was further separated by years groups [25], 1991–1995, 1996–2000, 2001–2005, 2006–2010, 2011–2015, but searchable by years, concepts or authors. The last process phase was determined on the concepts (TOP 44) represented by a matrix that evidence a combinatorial frequency between pairs of concepts. It should be noted that the concepts were transcribed from the publications to the repository of collected data. We use Social Network Analysis (SNA) techniques to obtain the empirical results.

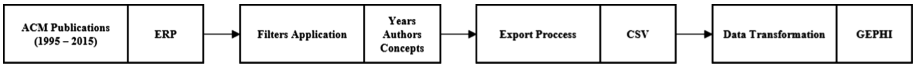

Fig. 1. Study methodology.

After filtered data, were exported to CSV (Comma-separated values) and made available for import through SNA tool. The software that we select was Gephi. This software is one of the most used open source tools intended for data network analysis graphs. The metrics provide results, such as the number of times the concepts (Table 1) appear in the network, the level of centrality, that is, the level by which the concept relates to other concepts and the proximity degree of each concept to others. The social networks analysis, associated with graph theory has been prevalent among researchers, especially in the engineering field [26]. Through the measures used by social networks analysis and in relation to this study, specifically the measures of centrality, we were able to describe the network structural properties (concepts and their relations) that determine indicators in a sense to perceiving for example, the cohesion degree between the different nodes (in the case of this study, the concepts). The edges number incident on a given concept is called by the degree of the concept (vertex). A graph whose number of edges is zero is called a depleted or empty graph [27]. The more connections there are in a concept, the more central is the concept of the network itself. This metric

determines an index that reflects the quality by which the network is interconnected between the various concepts (nodes) [28]. The minimum length path is defined as the smallest (geodesic) path between two vertices of a given network. If there is no path between two concepts, then there are connected subgraphs, also known as, related components [27, 29]. Closeness is another centrality measure that measures the proximity of a concept to other concepts. The closer a specific concept is to others, the higher the degree of closeness, and therefore, the higher the relationship between concepts [30]. The betweenness measure allows measuring the capacity that a particular concept must influence other concepts of the network. The larger this capability is the more central and essential the concept in the network [30]. The measures of degree, proximity, and betweenness are considered the primary measures of centrality [30] and for this study, were considered necessary, for this investigation.

Table 1. Study concepts

Concepts				
Adoption	Collaboration	Decision support	Integration	SAP
AHP	Cloud computing	E-business	Knowledge management	Simulation
Balanced scorecard	Control	E-commerce	Knowledge transfer	SME
Business information systems	Critical success factors	Enterprise systems	MES	SMEs
Business intelligence	CRM	ERP implementation	Open source	SOA
Business process	CSFs	Evaluation	Organizational change	Supply chain management
Case studies	Customization	Information systems	Organizational culture	Survey
Case study	Data envelopment analysis	Information technology	Project management	Web service
Change management	Data mining	Implementation	Risk management	

4 Results

The Gephi software was the tool selected to analyse the data on SNA. As already mentioned, the study in question only concentrates its interest in centrality measures. It is important to mention that for a better understanding of this empirical study, that the objective was to identify concepts directly related to the "ERP" word or acronym synonym. Thus, it is true that only data nodes (concepts) with a degree higher than zero should be considered for data analysis. The matrix developed focuses on the intersection of each one of the concepts (top 44) with all others (n−1), in this way we can

see that dimension has the relationship between all the concepts considered. Between 1996 and 2015, the following concepts (nodes) and connections (edges) were considered in Table 2. From the observation of this table (Table 2), it can be deduced which concepts were more clearly related to each other, between 2006 and 2010. It is also noticeable that between 1996 and 2000 the relations between the concepts were practically non-existent, suggesting that the concept of ERP began to create its ecosystem from the year 2001. After processing the data with Gephi, we obtained analyses individualized by period and by different metrics. The next table (Table 3) presents the results centrality measures of concepts that were shown more evident. Periods A, B, and C correspond respectively to the years 2001–2005, 2006–2010 and 2011–2015. The period 1996–2000, although analysed, is not presented in the table, because it presents a weak expression in relation to the concept's relationship. However, during this period authors began to relate the ERP with other concepts, such as "integration," "customization," "SME," contributing to the growth of the ERP ecosystem of next years. According to Table 3 and specifically with regard to the intermediation measure, we discover which concepts have marked its presence in all periods, thus marking a constant degree influence on ERP ecosystem. Examples of this are, "CRM," "Information Systems," "Integration," "Supply Change Management," "ERP Implementation" and "Implementation." It is also visible through the results presented in the degree centrality measure (Table 2) that, there are evident relationships between different types of other information systems (Table 3) and ERP systems, examples of this are, "CRM", "Supply Chain Management", "Business Intelligence", "Data Mining", "E-commerce", "Decision Support" and "MES". However, "Information Systems," "Enterprise Systems," "ERP implementation," "Integration," "MES" and "Change Management" are the most popular concepts of these networks since they have a greater centrality degree (Fig. 2). According to the Closeness centrality measure, although the values are very close to each other, the non-rounded values of "Implementation" and "Integration" are the highest values with 0.707 and 0.683 respectively, which were verified in the period 2006–2010 (Fig. 2). Thus, being the concepts with the shortest (geodesic) distance to all members of the network, which makes them closer to all. Analysing the values of the intermediation centrality measure, it is also the "Implementation" and "Integration" concepts that registered the highest values, with 163, 933 and 139, 686 respectively (Fig. 2). Also, through graphical analysis (Fig. 2), we can perceive what the computational results describe, that is, a visible growth related to the relationship of the concept throughout all periods. We note too that network has an increasing dimensional evolution from period to period and with stronger links between concepts. Figure 3 represents the type of relationship that exists between the concepts most used by the various studies selected for this research in respect to centrality degree between 1996 and 2015. The degree of centrality shows the number of connections of each concept (node) [31]. Thus, it is possible to understand the involvement that each concept has between itself and in a global way, the importance that each concept assumes by all ERP ecosystem. It is clear from the graphic evolution that over the years that the ERP ecosystem, evolved by diversified with other concepts and other subsystems, in organizational management scope [31].

Table 2. Evolution of the concepts (Nodes) and relations (Edges) in the period of analysis (1996–2015).

Period	Nodes	Edges	Average degree	Average weighted degree
1996–2000	10	8	1.60	1.6
2001–2005	27	45	3.33	5.11
2006–2010	42	194	9.24	21
2011–2015	41	128	6.24	12

Table 3. Centrality measure results

Concepts	Centrality measures								
	Degree			Proximity			Betweenness		
	2001 a 2005	2006 a 2010	2011 a 2015	2001 a 2005	2006 a 2010	2011 a 2015	2001 a 2005	2006 a 2010	2011 a 2015
Business intelligence	–	5.0	8.0	–	0.5	0.5	–	1.1	23.5
Business information systems	–	13.0	4.0	–	0.6	0.4	–	18.1	–
Business process	–	7.0	5.0	–	0.5	0.4	–	5.1	39.0
Change Management	1.0	21.0	–	0.3	0.7	–	–	53.4	–
CRM	4.0	7.0	5.0	0.4	0.5	0.4	19.4	5.1	18.7
Data envelopment analysis	1.0	5.0	2.0	0.3	0.4	0.4	–	40.7	–
Data mining	–	7.0	1.0	–	0.5	0.3	–	6.0	–
Decision support	1.0	4.0	10.0	0.3	0.4	0.5	–	–	37.0
E-commerce	2.0	3.0	3.0	0.4	0.4	0.4	–	0.5	41
Enterprise systems	5.0	18.0	12.0	0.5	0.6	0.5	44.9	35.5	–
ERP implementation	6.0	20.0	11.0	0.5	0.7	0.5	30,0	63.4	24.4
Evaluation	–	13.0	10.0	–	0.6	0.5	–	21.3	101.9
Information systems	4.0	22.0	18.0	0.4	0.7	0.6	25.4	96.7	168.3
Implementation	12.0	25.0	18.0	0.6	0.7	0.6	165.0	139.0	101.3
Integration	7.0	23.0	9.0	0.5	0.7	0.5	86.6	139.7	35.8
MES	–	17.0	8.0	–	0.7	0.5	–	93.1	7.5
SME	–	15.0	16.0	–	0.6	0.6	–	56.7	162.2
Supply change management	2.0	8.0	4.0	0.3	0.5	0.4	25.0	8.6	7.9

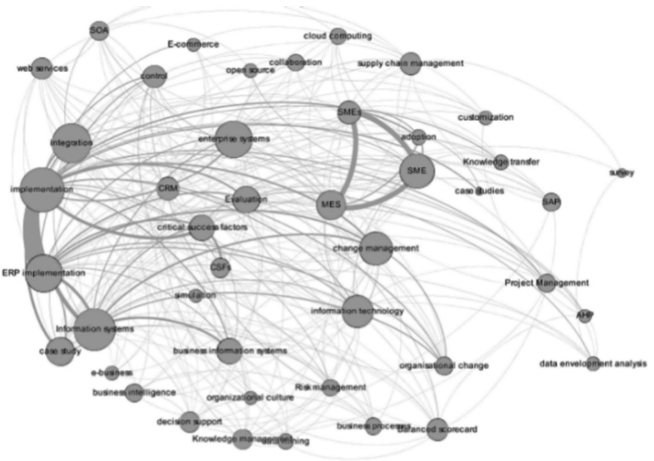

Fig. 2. Graph of the concepts by higher weight of the centrality measures between 1996 and 2015

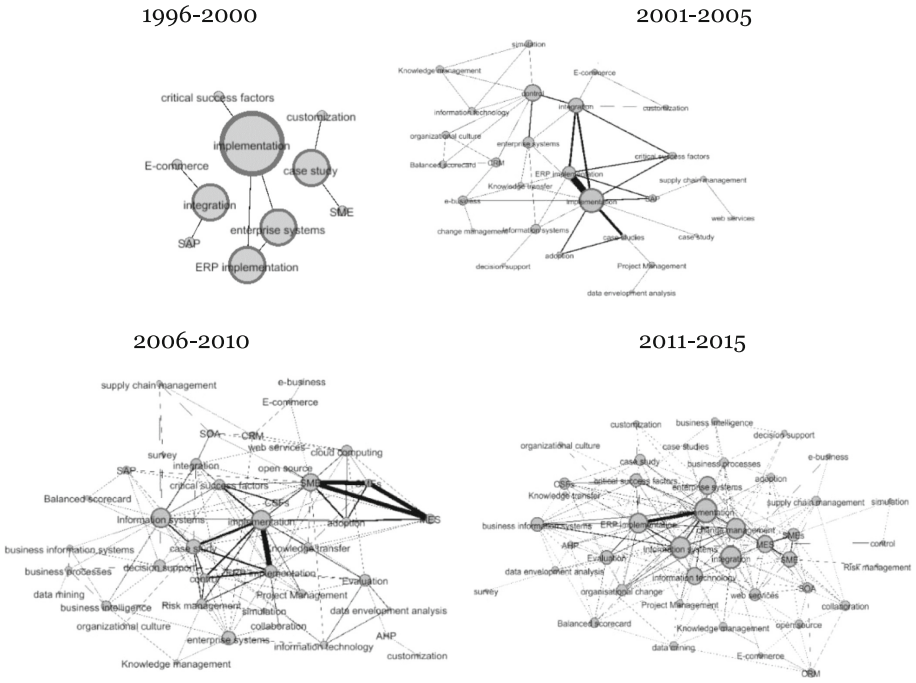

Fig. 3. Centrality evolution measures by period,

4.1 Discussion

Many studies have been developed about the ERP context in recent years [32–34]. There is also a growing interest by the information technology researchers regarding the socio-technical information systems analysis, namely applying methodologies in their studies through SNA [27, 35–39]. However, we did not find any study that used SNA that related ERP with associated concepts, in the sense of interpreting the interrelation between them. The work developed is in this study and in line with the literature review. The SNA (Social Networks Analyzes) has proved to be an effective method with respect to the comprehension of the complexities of a social network [40], namely in the case of this work, the perception of the degree of connectivity between the concepts associated to the studies of the most diverse authors about the ERP. The social bonds are established under concrete prisms and with common interests of each concept [27]. From this point of view, it seems to be clear that the concepts closest to the ERP have had a more continuous relationship than the more distant concepts (over the years) for this reason they were many times natively integrated with the ERP itself. This is the case of the concepts as "integration," "SME," "CRM," "SCM." However, the study presents concepts such as "implementation," "information systems," "enterprise systems," "project management" which are not precisely subsystems or information systems, are abstract and generic concepts that provide an important proof of the existence of a strong multidisciplinary environment, around the ERP ecosystem. As we have already mentioned, although there are many studies on the evolution of ERP and other information systems, we did not find any study to specifically use SNA to demonstrate the relationship between all the actors across ERP (subsystems and concepts). On the other hand, the SNA has been presenting a growing demand by the researchers, as a research method, in the field of studies in the area of sciences and information technologies thus legitimizing, the methodology chosen for this study [41].

5 Conclusions and Future Work

In this study, it was tried to show that the ERP developed a complex ecosystem over the years, based on the own technological evolution and consequently of many and new organizational challenges. The analysed data confirm that the ERP has been following the new technological paradigms and organizational challenges. The integration capability that ERP has been developing over the years with other information systems or subsystems has made ERP one of the most versatile and popular solutions on the market. Also, over the years, the implementation of ERP has been a subject increasingly discussed by researchers. The study showed the centrality measures importance, in the case of this study, regarding the relationship that exists in the ERP with the organizational processes and the technological evolution. We conclude that today, ERPs continue to be very current solutions and with expectations of growth vis-à-vis their ecosystem developed over more than 25 years, given its capacity for interoperability between technical evolution and organizational evolution. As future work, we understand that it would be important in the ERP context, the evolution of the ERP itself and the ability to integrate it with the impact of the new technological paradigms,

namely the issue of IOT (Internet of the things) and artificial intelligence. Also, will be useful as scientifically contribution that within the organizational management scope, a study that investigates the impact that top management has on the technology capture for new business processes, and understands the effect that this fact has on the ERP success.

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