EVOLUTIONS AND TRENDS IN INFORMATION SYSTEMS ASSISTING MANAGERIAL DECISION-MAKING. STUDY ON ERP SYSTEMS

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***Abstract**: The aim of this paper is to describe the evolution of information systems used in managerial decision-making, as well as their transformation under the current economic conditions. The main phases underwent by ERP (Enterprise Resource Planning) information systems are described, as well as the current perspectives in their development and the opportunities brought about by these systems in the era of globalization. Furthermore, the present paper aims to carry out an analysis, using fuzzy sets, to identify the optimal system, on the basis of multiple criteria of varying importance.*

***Keywords:** ERP, decision support, ERP evolution, fuzzy sets.*

1. INTRODUCTION

An information system is that system which is capable of performing data ***acquisition*** through either manual or automatic procedures, data ***storage***, ***processing***, and perhaps the most important function, ***conversion*** of data into information.

The resulted information may take various shapes, however, it's ultimate aim is to facilitate the decisional process, in order to ensure an enterprise's sustainable growth. The main components of an information system are: the computer (terminal), computer networks, servers, the database, software resources, and last but not least, the users. An alternative approach to the information system is that it may be considered a language which supports decision-making, and facilitates the actions undertaken by employees.

Currently, along with the globalization of the economy, the decision-making process has become increasingly complex, forcing managers to adapt, by adopting dedicated software in order to come to optimized, clear and precise decisions. ERP systems are a prime example, given that they contain model libraries, intended for the optimization of the decision-making process, and which can be tailored for each enterprise, regardless of their size, purpose or geographical position [1].

As the formalities associated with international trade are increasingly simplified, and with the expansion of online commerce, a company may have branches in multiple countries, may separate the production and managerial activities, and may operate on more than one market, in order to enlarge its customer base.

Under these conditions, in order to maintain high standards and to optimize processes, real-time communication is an absolute necessity. This necessity can only be fulfilled by having a finely tuned information system, focused on the requirements of the company in question.

Finally, an information system needs to ensure complete data security, a vital aspect in the case of network use (either internal and/or the Internet), given the added risk of unauthorized access to data or even fraud [2].

2. INFORMATION SYSTEMS CLASSIFICATION

Over the years, various authors have contributed to the design of a theoretical framework regarding information systems, based on conventional company hierarchy. Laudon & Laudon (2012) characterize the information system as being composed of the elements that collect, process, store and distribute information which is intended to support decision-making and control over organizations. Thus, information systems include three distinct aspects: organization, technology and human resources. These can be classified according to the level at which the decision is made, as illustrated in figure 1 [3].

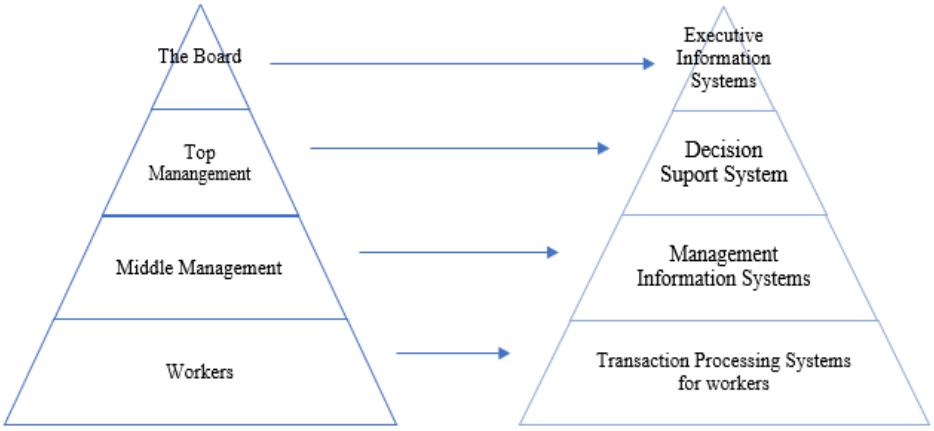

FIG. 1 The information system pyramid – adapted from *Four level pyramid model of information systems* (O´Brien & Marakas, 2010)

At the level of operative employees, information systems need to support the control and supervision of basic activities of the company's transactions, which has led to these systems being termed *transaction processing systems.*

Information systems employed in management and decision-making systems collect data from the transaction processing systems and transform them into information that managerial decision will be based on. These can process a vast quantity of data in real-time and include analysis instruments and predictions that are vital for the optimization of the enterprise's processes.

Executive informatic systems are employed in devising strategic medium to long-term decisions. These analyze both internal and external data in order to anticipate fluctuations which could affect the competitiveness of the enterprise [4].

In the book Decision Support Systems: A Knowledge-Based Approach (1996), the characteristics of a decision-support information system are described as follows:

- Its design should reflect a solid knowledge base pertaining to the domain approached by the decision process;
- It allows for the acquirement of descriptive knowledge or the inference of procedures and rules;
- Offers the opportunity of presenting information on the spot or for the periodic generation of a detailed report;
- It facilitates the selection of certain knowledge sets which may be studied or included in the decision-making process;
- It is meant to ensure constant interactivity between the system and the deciding department of the organization [5].

Despite the pyramid model remaining theoretically useful, at the practical level a number of innovative technologies have been introduced, and novel categories of information systems have been developed. These do not fall under the previously described pyramid model.

The following are among the most significant examples:

- Data warehouse;
- BI Model;
- ERP (Enterprise Resource Planning) software.

A data repository is a database with a unique data structure which allows for the quick and efficient extraction of information from a large quantity of data [6]. At the same time, this system is employed in data analysis and report and is considered a significant part of the BI Model (Business Intelligence Model). Data repositories store current and historical data, which is used for the creation of analytic reports that concern all the employees of the company [7]. The data repository constitutes an alternative to traditional databases.

The BI Model (Business Intelligence Model) advances the possibility of obtaining key information regarding day-to-day activities, but can also generate an analysis of medium to long-term opportunities and risks. The market for this particular model has increased significantly in recent times; there are more and more companies investing considerable capital in BI Models [8]. However, the majority of BI systems are directly correlated with the data structure that they linked to, generating exhaustive statistics which can be hard to comprehend regarding the general business strategy. A recent study concerning BI users indicates that one of the system's drawbacks is its low flexibility [9].

The ERP (Enterprise Resource Planning) is a software package that ensures the integration of the entirety of information pertaining to an organization into a single platform. The purpose of ERP systems is to ensure the transparency of data in an organization and to facilitate access to any kind of information that may be instrumental to the organization's goals. ERP systems analyze cash-flow fluctuations, material and raw material resources, production capacity, the status of business commitments (the purchase and sale process) and the human resources. This system is modular and is built on the basis of data collected from multiple departments such as: manufacturing, the purchase department, the sales department, accounting etc. [10].

Concurrently, ERP systems improve the flow of information between all business functions and manage the connections with interested parties (shareholders, state institutions, clients, potential investors) [11].

3. THE EVOLUTION OF ERP SYSTEMS

ERP systems have undergone continuous improvement since the advent of their precursors, being constantly upgraded in order to respond to economic market changes and technological development. The earliest proposal of an enterprise resource-planning system emerged 60 years ago with the development of Inventory Control Packages (IP), developed as frameworks, written in one of the following programming languages: COBOL, ALGOL and FORTRAN.

Seeing that any system can benefit from an upgrade, new modules are being tested, which will be integrated into the system of future ERP generations. The expected outcome is the enhancement of the decision-making process and the generation of more reliable predictions. In addition, ERP systems are becoming increasingly flexible, customized, with both local and cloud storage capabilities, modularized into multiple interconnected applications which can be changed individually. These are known as postmodern ERP systems [12].

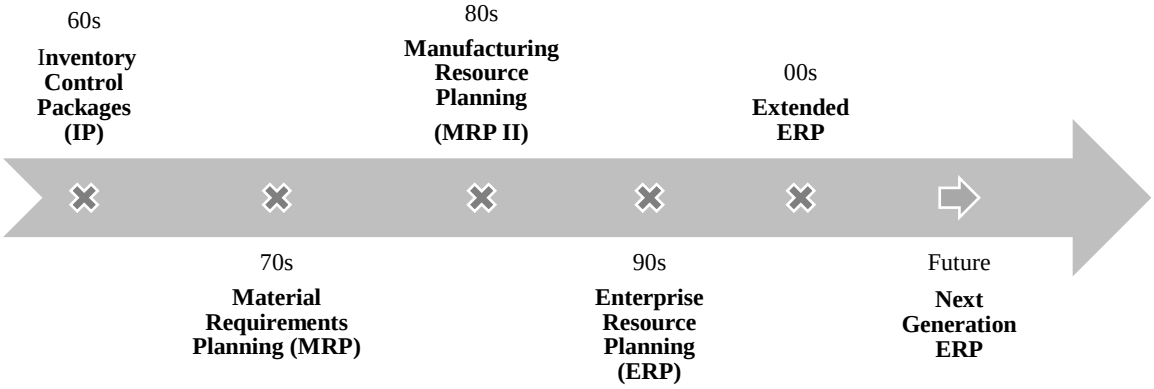

FIG. 2 The evolution of ERP – adapted from Kasem, Ramy & El-Bakry, Hazem & Saleh, Ahmed. (2017). *Surveying Systems of Enterprise Resource Planning. International Journal of Advanced Research in Computer Science & Technology.*

Inventory Control Packages – provide accurate real-time analysis, optimization and prediction procedures, aimed at solving complex supply management issues [13]. The most important functions of an inventory control system are:

- The function of controlling and predicting inventory, using multiple algorithms to identify anomalies and potential issues;
- The function of inventory optimization;
- The purchase and inventory dimensioning function, using inventory calculations;
- The function of calculating emergency inventory and working capital;
- The function of managing inventory-associated costs (storage, transportation, etc.);
- The function of determining the duration of an inventory-cycle;
- The function of logistic support and of multiple locations;
- The function of inventory object management [14].

Specialty literature describes two inventory control methods: a periodic control system (typically the end of an accounting year) and a perpetual control system which thoroughly monitors all stock movements.

The perpetual control system has the advantages of more detailed control, as well as decreased storage cost of products, materials and raw materials. However, its setup requires more time and financial resources.

Material Requirements Planning, abbreviated as MRP is a production planning system by means of inventory control and detailed planning of fabrication processes. The novelty brought by these MRP systems compared to inventory control packages is that they solve three major problems:

- They ensure the availability of supplies for production and of products that are to be delivered to clients;
- They plan the production processes, delivery deadlines and material purchasing processes;
- They maintain low storage costs for materials and products.

In 1983, Oliver Wight develops MRP into **Manufacturing Resource Planning**, abbreviated MRP II [15]. The MRP II system improved upon previous systems by the integration of all the aspects of the fabrication process, including materials, finances and human resources. One similarity to present-day ERP systems is the centralized storage and processing data, by means of a centralized database. 1980's technology (hardware, software and relational databases) were insufficiently developed to be able to provide real-time information [16], and the costs of those systems proved prohibitive for the majority of enterprises. Together with technological improvements and the trend set by the MRP II systems in data processing, the foundation was laid out for the integrated systems and more accessible software presently used by businesses [17].

Enterprise Resource Planning is a software product that integrates the entirety of an organization's information into a single platform. The purpose of this system is to ensure the organization's data transparency and to facilitate the access to potentially useful data. ERP provides an integrated, continuously updated assessment of the basic business processes, using common databases, maintained by a database management system. ERP systems monitor business resources – cash, raw material, production capacity – and the status of business arrangements: orders, purchases and salaries. The applications of which the system is made up share data from multiple departments (production, purchases, sales, accounting etc.) [1]. ERP facilitates the flow of information between all functions of a business and manages links with interested external parties.

4. THE CRITERIA FOR SELECTING AN ERP SYSTEM

Understanding the environment in which the information system is to function is the first step of the analysis phase. The study of the internal environment of the economic entity which will make use of the information system comprises the following activities: identification of general information pertaining to the organization, awareness of the entity's activities, consideration of its management characteristics, as well as knowledge of all technical means at its disposal [5].

In order to generate a detailed analysis, this paper aims to make use of fuzzy sets, that allow for the breakdown of insufficiently clarified phenomena, since for each element of said sets there are multiple intermediary degrees of membership, from full membership to non-membership [1].

Modelling the managerial decision using fuzzy methods requires the modelling of imprecise, subjective, linguistical data that occur in the real-life situations of the decisional process.

According to Tom Miller, some key criteria that are useful for choosing an ERP system are:

- Decision-making support provided to upper management – labeled **C1**;
- Product support provided to the users by the producing company – labeled **C2;**
- Integration with existing systems – labeled **C3**;
- Monthly maintenance and update cost – labeled **C4**;
- Employed technology and potential capabilities – labeled **C5**;
- The prospect of customization according to the organization's requirements – labeled **C6** [18].

These six criteria have been weighted distinctly. Thus, C1 is 20%, given that in the calculation of system performance this criterion occupies the first positions; C2 is 25% given the importance that is carried by a sound implementation and utilization of the system by the employees; C3 is worth 15% because system modification is a lengthy and costly process; C4 is weighted 20% since the running costs of the system, as well as its support and maintenance result in considerable expenses; C5 is weighted 15%, the ability of using the system on all available devices and the ability to use cloud technology are essential; C6 is worth 15%, given the potential competitive advantage generated by a system's conformity to the specific characteristics of a business.

Criteria C1, C2, C3, C5 and C6 were graded on a scale from 1 to 10, where 10 is the maximum grade a system can receive. In addition, the C4 criterion's values are written in a fuzzy triangle, where the first value is the minimum, the second value is the mean of the expenses and the last value is the maximum expense.

ERP information systems were randomly selected from the paper „Top ERP Software Comparison" [19], and were labeled E1 to E5, omitting the name in order to avoid advertising.

Table 1. Outcome matrix. "Maximum" indicates "the higher the better" criteria, „minimum" indicates "the lower the better" criteria.

	C1 (maxim)	**C2 (maxim)**	**C3 (maxim)**	**C4 –$ thous. (minimum)**	**C5 (maxim)**	**C6 (maxim)**
E1	7	7	9	(2, 4, 5)	9	8
E2	7	8	8	(1, 3, 6)	9	7
E3	8,5	9	6	(6, 7, 9)	10	8
E4	10	8	10	(13, 17, 27)	10	8
E5	9	9	8.5	(14, 19, 26)	10	8
Weight %	**20%**	**15%**	**15%**	**20%**	**15%**	**15%**

In order to convert each fuzzy triangle to a single value, the following formula was used:

$$X = \frac{1}{4} * (x_1 + 2*x_2 + x_3)$$

Table 2. Outcome matrix after calculation of the fuzzy triangle

	C1 (max)	**C2 (max)**	**C3 (max)**	**C4 – $ thous. (min)**	**C5 (max)**	**C6 (max)**
E1	7	7	9	3,75	8	8
E2	7	8	8	3,25	9	7
E3	8,5	9	6	7,25	10	8
E4	10	8	10	18,5	10	8
E5	9	9	8.5	19,5	10	8
Weight %	**20%**	**15%**	**15%**	**20%**	**15%**	**15%**

In order to determine the degree of membership for each criterion, the aspiration level and the margin of error were taken into account.

Table 3. Aspiration level and margin of error for each criterion

	C1	C2	C3	C4	C5	C6
Aspiration level (S_E)	9	8	9	7	9	9
Margin of error (δ_j)	1	2	3	5	2	2

The degree of membership takes values from 0 to 1, where 0 means that the value is larger than the aspiration level plus margin of error (for "the lower the better" criteria) or is below the aspiration level after subtracting the margin of error. In order to calculate the degree of membership, the following formulas were used:

- For "the higher the better" criteria:

$$X = \begin{cases} 1, & x_i \geq S_j \\ 1 - \frac{S_j - x_i}{\delta_j}, & S_j - \delta_j < x_i < S_j \\ 0, & x_i \leq S_j - \delta_j \end{cases}$$

- For "the lower the better" criteria:

$$X = \begin{cases} 1, & x_i \leq S_j \\ 1 - \frac{x_i - S_j}{\delta_j}, & S_j < x_i < S_j + \delta_j \\ 0, & x_i \geq S_j + \delta_j \end{cases}$$

where:

E = the cases included in the calculation;
x = value taken by one criterion in one case;
s_j = the level of aspiration for that criterion;
δ_j = the margin of error for that criterion.

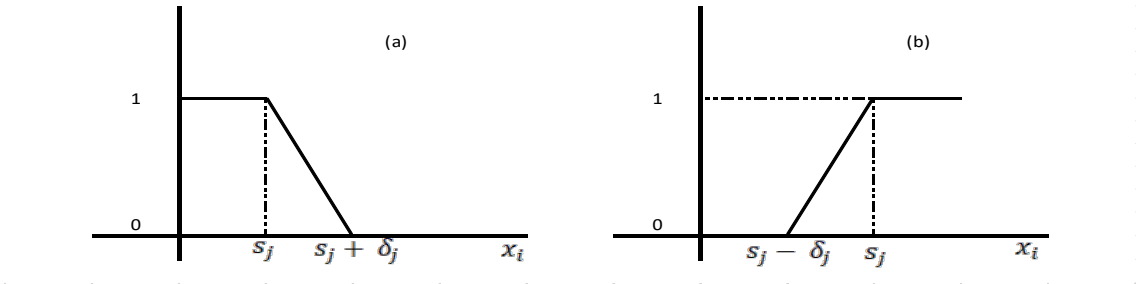

FIG. 3 Membership function: (a) "the higher the better" criteria, (b) "the lower the better" criteria
Source: Adapted from Lixăndroiu D. *Modelarea deciziei economice*, Ed. Economică, Bucharest 2014, p. 187, figure 5.10.

Following the application of formulas in all the cases, the outcome matrix was rebuilt, containing values in the [0,1] interval, which stand for the degree of membership for each of the criteria of every information system.

Table 4. Outcome matrix

	C1 (max)	C2 (max)	C3 (max)	C4 – $ thous. (min)	C5 (max)	C6 (max)
E1	0	0.5	1	1	0.5	0.5
E2	0	1	0.67	1	1	0
E3	0.5	1	0	0.95	1	0.5
E4	1	1	1	0	1	0.5
E5	1	1	0,84	0	1	0.5
Weight %	**20%**	**15%**	**15%**	**20%**	**15%**	**15%**

The final step in the analysis was the calculation of the weighted mean for each ERP system, taking into consideration the weight of each criterion.

Table 5. Outcome matrix

	C1 (max)	C2 (max)	C3 (max)	C4 – $ thous. (min)	C5 (max)	C6 (max)	Weighted mean (φ)
E1	0	0.5	1	1	0.5	0.5	0,575
E2	0	1	0.67	1	1	0	0,6
E3	0.5	1	0	0.95	1	0.5	0,665
E4	1	1	1	0	1	0.5	0,725
E5	1	1	0,84	0	1	0.5	0,7
Weight %	**20%**	**15%**	**15%**	**20%**	**15%**	**15%**	**100%**

The optimal decision will by determined as such:

$$E_{optim} = \{ E_i \mid \max \varphi(E_i),\ E_i \in \mathrm{E} \} = \mathrm{E4}$$

Following the analysis, it was concluded that the most advantageous ERP information system was the system designated **E4**, which had the highest weighted mean of the membership degrees, 0,725 to be exact.

Thus, it can be surmised that the E4 system has a compliance to the imposed criteria of 72.5%, therefore being the optimal choice. Not far behind is the **E5** system, obtaining a score of 0.7, signifying a 70% accordance with the imposed criteria. At the opposite end is the **E1** system, with a score of 0.575 and a compliance degree of 57.5%.

5. SWOT ANALYSIS OF ERP SYSTEM IMPLEMENTATION

A SWOT analysis is a technique used in a business environment to reveal the **S**trengths, **W**eaknesses, **O**pportunities and **T**hreats. Strengths and weaknesses are attributes of an economical entity's internal activity, whereas opportunities and threats refer to market influences over the organization. Concerning the opportunities, the company may choose to take advantage, while in the case of threats it may protect itself, but cannot alter them.

Table 6 SWOT analysis of ERP system implementation

	Helpful to achieving the objective	**Harmful to achieving the objective**
Internal origin (attributes of the organization)	**Strengths ↓**	**Weaknesses ↓**
	• Enhances the decision-making process; • Optimizes the purchases and sales processes; • Improves relations with the clients; • Improves communication between departments; • Decreases manual processes and increases automation; • Utilizes a business model; • Enhances process control.	• High monthly cost; • Product support is in English– employees need to speak English; • Employees may be hesitant to change; • Inadequate understanding and use of the system; • Prolonged employee training time to avoid errors; • Insufficiently developed technology; • Lengthy system implementation.
External origin (attributes of the environment)	**Opportunities ↓**	**Threats ↓**
	• Competitive advantage over those who did not implement ERP systems; • Development of existing technology and control methods; • Emergence of new business models; • The process of globalization and the necessity for real-time knowledge of the data; • The increase of market-value of the ERP system providers; • The European legislative context; • Artificial intelligence.	• Low proficiency of the workforce in utilizing an ERP system; • The rise of support and maintenance costs; • System security and the risk of information leaks; • Technological upgrade; • The high cost of changing the ERP system and the dependence on one ERP system provider • Limitations in the management process; • Market saturation.

6. FUTURE TRENDS IN ERP SYSTEMS

Currently, technology is being developed at a rapid pace, which forces the ERP system providers to adapt to the technological progress. Market saturation, online commerce and the emergence of artificial intelligence are a few of the problems that must be addressed in order to create a high-performance ERP system. Changes to ERP systems will drastically impact any companies that employ such systems.

ERP systems are intended for high-turnover companies, both because of the high cost, as well as the large amount of data typically used.

Given the market saturation, integrated information system producers are driven to new markets, which require price reduction strategies in order to make the product financially viable. Additionally, the implementation and configuration system is constantly improved, so that system changes are not stressful for the employees.

Artificial intelligence and the increasingly efficient sharing of data inside these systems has improved data collection and analysis and has led to the simplification of all processes. Further development of artificial intelligence will lead to the automation and optimization of all processes, which may contribute to improved production cost prediction for all products that are to be sold. Additional information generated by ERP systems will help managers implement increasingly well-informed decisions, by using data processed using advanced analyses.

Additionally, management may improve efficiency and productivity by using this information to select the most beneficial updates for various business processes [20].

Another step in the evolution of ERP system is the development of iERP (intelligent Enterprise Resource Planning) systems, which use machine learning technology and advanced analysis procedures, which is a welcome upgrade to the existing capabilities of traditional ERP systems. Another improvement brought about by intelligent ERP is that this system is capable of learning exceptions, constantly evolving and adapting to market challenges. Additionally, iERP can reuse information and previous responses whenever a more complex analysis is necessary.

iERP systems will incorporate social media modules, facilitating internal communication, as well as communication with business partners. Additionally, increasingly prompt responses to both employees and consumers, will be a considerable improvement brought about by social media upgrades to ERP systems.

CONCLUSIONS

Selecting an appropriate ERP system is a challenging task, given that it generates significant monthly costs, and requires a prior, detailed analysis. Since no system is perfectly compliant to the requirements of an organization, this paper presents a comprehensive, multiple-criteria analysis, using fuzzy sets, in order to assist users in selecting the most appropriate package for their needs.

Following the analysis, it was concluded that the ERP system that had the highest weighted mean of the degrees of membership to the criteria had accumulated 0.725 points, signifying a 72.5 % compliance to the imposed criteria, and thus being the optimal solution.

ERP systems are undergoing constant development, ever since their precursors in the 60's, their current characteristics being susceptible to improvement. In the future, these systems will include artificial intelligence technologies, which will optimize production and management processes and reduce their cost.

In addition, artificial intelligence and machine learning technology will be capable of utilizing increasingly complex databases and greater quantities of data, which will facilitate the decision-making process by generating more precise predictions.

Furthermore, ERP systems will undergo considerable upgrades. By fusing with various other technologies, these platforms will offer additional information to enterprises, which may contribute to improved financial decisions.

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