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ANALYTIC NETWORK PROCESS IN ERP SYSTEM SELECTION

Abstract

An Enterprise Resource Planning (ERP) system has a major impact on a company's performance; therefore it is a critical investment. This paper presents a framework for selecting a suitable ERP system using the Analytic Network Process (ANP) methodology. The proposed framework establishes a set of criteria with respect to the support of business goals and enterprise strategies. The method is explained on a numerical example based on the choice of an ERP for a small manufacturing enterprise.

Keywords

ERP system selection, Analytic Network Process (ANP).

Introduction

The first years of the 21st century show a highly dynamic market, fierce market competition, global call for an effective way of doing business. One of the main assets is an information system. Various methods and procedures are combined in many ways and into various subsystems to create what may be called an information system. Early business information systems were limited to the information processed by accounting systems, or, in a production enterprise, to inventory control systems. Today such systems must integrate information from all resources in the enterprise. They are known as Enterprise Resource Planning systems (ERP), which are complete information systems, that can support an enterprise by integrating all its data assets and automate some of its business processes.

From the systematic point of view, if an enterprise has problems with resource planning and wants to improve its processes, the way to change the current state into a desired one is to choose a new ERP system.

A successful project involves the selection of a vendor and a software application, as well as implementation and verification of the system selected. Because of the complexity of business environment, limitation of available financial resources and system availability, the selection of an ERP system is a very difficult, and at the same time an important element of a project; a wrong choice leads to implementation which could be very difficult, time consuming and very expensive [Wei, Chien, Mao Wang, 2005]. Most of the existing ERP systems are similar, but also have fundamental design differences. Different companies have different needs, business models and key business processes. Although the system must have the functionalities desired, not all systems are suitable for every company. Therefore companies must carefully organize the process of the selection of an ERP system.

There are many different quantitative techniques being used for the ERP system selection problem, such as: ranking scoring, mathematical optimization, Analytic Hierarchy Process (AHP), Quality Function Deployment (QFD), DEA, etc. However, many of these methods have limitations and don't include a wide spectrum of expert knowledge in selection criteria.

In this paper a new, easy and flexible proposition of ERP system selection is given. The proposition is based on the Analytic Network Process (ANP) methodology. ANP is an extension of AHP [Rao, 2000], a well known decision making method proposed by T. Saaty. The ANP method is a more general form of AHP, incorporating internal and external dependencies among the decision model's elements and alternatives [Percin, 2008]. The full description of the model can be found in [Saaty, 1999]. The main aim of this paper is to adopt ANP methodology to ERP system selection, with the proper choice of criteria.

This paper is organized as follows. After a short introduction to the ERP system selection problem, in the first chapter ERP systems are presented. In Chapter 2 a description of the proposed method for the ERP system selection, based on the ANP methodology is given. In Chapter 3 a case study is presented. A small enterprise intending to implement an ERP system is described. The aim of the ERP system implementation in that enterprise and the criteria applied are shown. In Chapter 4 a numerical example is given. Finally, overall conclusions are presented.

1. ERP systems

The acronym ERP was first employed in the early 1990s as an extension of the Material Requirement Planning (MRP) standard and later of the Manufacturing Resource Planning (MRP II) standard. Systems known today as ERP systems have no official standard, but generally such systems integrate internal and external management information across the entire enterprise, including manufacturing, finance and accounting, sales, service, human resource management etc. One of the most complete definitions is given by the American Production and Inventory Control Society:

An accounting-oriented information system for identifying and planning the enterprise-wide resources needed to take, make, ship and account for customer orders. An ERP system differs from the typical MRP II system in technical requirements such as graphical user interface, relational database, use of fourth generation language and computer assisted software engineering tools in the development of client/server architecture and open-system portability.

This definition points out that the main advantage of ERP is the ability to integrate most of the business functions. Owing to this, the company can easily and quickly analyze all business data from every organization area with respect to enterprise as a whole.

The current ERP development aims to utilize ERP to realize and sustain a competitive advantage. Complementary technologies are beginning to extend the functionality of enterprise application to include the Internet and telecommunication technologies to fulfill the needs of e-commerce [Wei, Chien, Mao Wang, 2005].

One of the most important characteristics of ERP systems is their modularity. Figure 1 presents the main modules of a typical ERP system, however, the number and names of modules may differ. A typical system integrates all those modules by allowing them to share and use all business data from one central database.

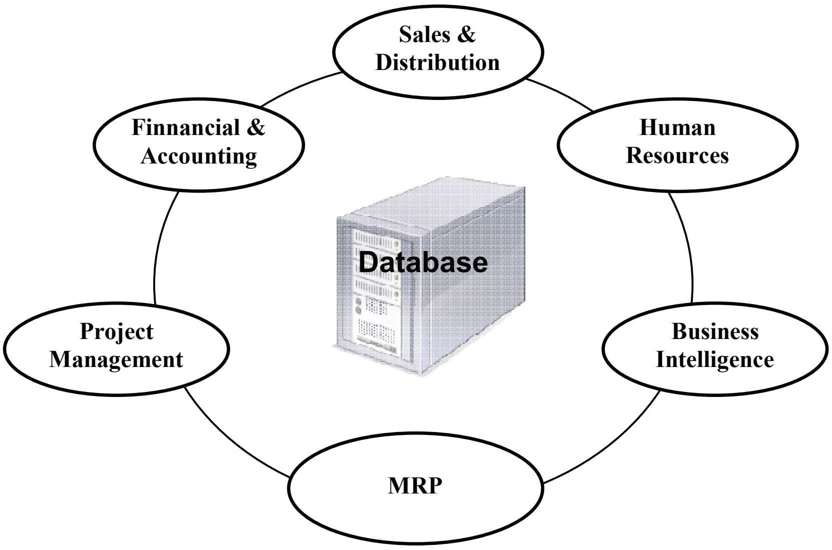

Figure 1. Main modules of an ERP system

2. Proposed Method for ERP system selection

The deployment of ERP system consists of two stages: selection and implementation. While most ERP packages have similarities, they also have design differences. Most papers about ERP explicitly focus on the critical success factors for the implementation process. The issue of the selection process for ERP software is for the most part ignored. Anyway, this issue is important, because, as the stage preceding the implementation process, it presents the opportunity for both researchers and experienced people to examine all the dimensions and implications (benefits, risk challenges, cost, etc.) of buying and implementing ERP software prior to the commitment of a formidable amount of money, time and resources. Hence a better understanding of critical factors could amount to substantial savings in terms of economics (actual cost), time and improved administrative procedures and could lessen the risk and uncertainty associated with the acquisition of these types of systems [Verville, Bernadas, 2005].

The proposed ANP model for the ERP system selection is given in Figure 2.

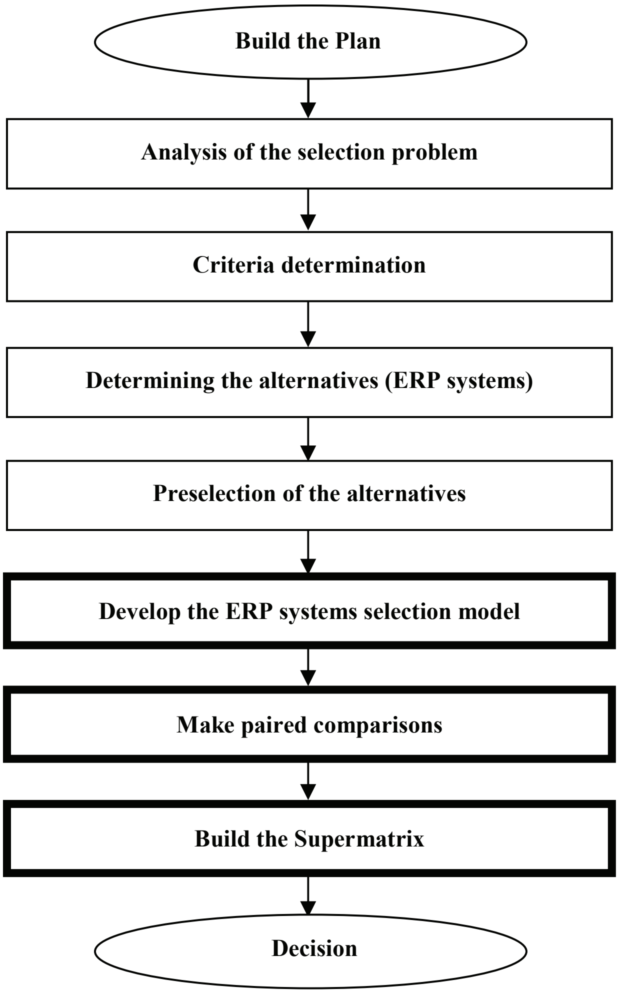

Figure 2. The proposed ANP model for ERP system selection

We explain each step of this model.

Step 1: The first step of the algorithm is the analysis of the selection problem. The main task at this stage is to form a project team, plan and collect all possible information related to the next stages. The plan should define the structure of the process and identify the general criteria of the ERP.

Step 2: In this step all criteria must be determined. In this paper we propose criteria divided into three main clusters as in Verville and Halingten [Verville, Halingten, 2002]:

Technical Features
Functionality Features
Vendor Factors

This is an extension of models proposed in the ERP selection problem (examples of these models can be found in [Percin, 2008; Wei, Chien, Mao Wang, 2005]). Most of them propose two main group of criteria: system factors and vendor factors, but the incorporation of technical features and redefinition of functionality features allows the team members to focus separately on the functionality and the technical aspects of ERP systems. However, those criteria are not the only possibilities, every project team should discuss the form of the ANP model in the context of the organization needs.

Step 3: During this step, a list of available vendors and technologies is created.

Step 4: If the list of possible alternatives is long, preselection is made.

Step 5: In this step an interaction network is created. The project team must identify all dependencies among the elements of the network.

Step 6: The alternatives from the short list are pairwise compared by expert judgments, according to the method proposed by Saaty [1999].

Step 7: During this step, the system's Supermatrix is constructed corresponding to the interactions in network created in step 5. The impact of a given set of elements in a component on another element in the system is represented by the ratio scale priority vector derived from paired comparisons in the same way as it was derived in the AHP method. Each priority vector is entered in the appropriate position as a column of the Supermatrix. The Supermatrix structure is shown in Figure 3.

$$W = \begin{matrix} \text{Technical} \\ \text{Functionality} \\ \text{Vendor} \\ \text{Alternatives} \end{matrix} \begin{bmatrix} W_{11} & W_{12} & W_{13} & W_{14} \\ W_{21} & W_{22} & W_{23} & W_{24} \\ W_{31} & W_{32} & W_{33} & W_{34} \\ W_{41} & W_{42} & W_{43} & W_{44} \end{bmatrix}$$

Figure 3. The Initial Supermatrix

In the structure above, the terms W_{ij} represent the sub-matrix of priority vectors derived with respect to a given element. In the Supermatrix the values W_{21} mean that the cluster "*Functionality features*" depends on the cluster "*Technical features*". In this step the consistency of each comparison is checked and analyzed.

Step 8: The Initial Supermatrix derived in step 5 is often called unweighted, because it consist of several normalized eigenvectors (priority vectors [Saaty, 2004]), and hence the entire column of the matrix may sum to an integer greater than one. The Supermatrix has to be stochastic to allow the derivation of meaningful limiting priorities. Saaty proposes to multiply the cluster weights by the corresponding elements in the Supermatrix [Saaty, 1999]. To get the cluster weights the standard pairwise comparisons algorithm is used. As the result we receive the Weighted Supermatrix in which each column sums to one.

Step 9: In the last step we compute the Limit Supermatrix. The Weighted Supermatrix is multiplied by itself, until the Supermatrix row values converge to the same value for each column of the matrix. This matrix yields the long-run or limit priority of influence of each element on every other element. The most suitable ERP system is that which has the highest priority.

As a result of this method we receive a scale of priorities. It is read from the Limit Supermatrix and then normalized.

3. Case study

3.1. Description of the enterprise

The enterprise under analysis belongs to the manufacturing and installation of steel construction market. It has been created as a result of the merger of three steel industry companies, specializing in various stages of the production cycle. This merger made it possible to service the entire production cycle, starting with the purchase of materials, through manufacturing, and ending with the final installation and service.

The strategic goal of the enterprise is to strengthen its position in the sector of steel construction manufacturing and installation. In the long-term, a dynamic growth of demand for steel products is expected, which is related to investments planned in the energy and oil industries. The company plans extensive investments, raising its competitiveness and production capabilities. Thanks to the diversification of revenues into trade, manufacturing, and services, the company is able to achieve a high margin and to decrease the risk caused by market fluctuations.

The company's focus is on distribution , manufacturing, and construction and installation services. Its main customer is the Polish market, but a part of the products goes to the European Union countries, Asia and South America. The company offers industrial constructions and equipment, bridge constructions, buildings with steel supporting structure, narrow-gauge railway junctions, installations and equipment for environmental protection. Additionally, the company's contractors can use the services of its design office.

The merger of such differentiated enterprises in one company involves many organizational problems. The necessity to arrange the processes of norm adjustment and to establish a system of information flow became a significant challenge for the company managers. Another problem has been created by the location of the individual firms within the enterprise. Their location is very advantageous because of their activities, but it makes the control and information flow between its individual branches more difficult. The board of directors has decided to implement an integrated management system, since the solutions used in the individual companies comprising the enterprise did not fulfill their functions enterprise-wide.

When analyzing the situation of an enterprise, we can distinguish several factors in favor of the implementation of an ERP. The basic factor is the necessity to arrange and make uniform the individual processes within the entire enterprise, to ensure integration of reporting originating in the individual companies, and to provide access to the resources and data of the enterprise. The introduction of an ERP system should contribute to the increase of control over the individual projects, to stock reduction and to storing costs decrease.

3.2. Goals of the ERP system implementation

The analysis of the requirements of an enterprise is based on the premise that an ERP system is selected for at least 5-6 years and therefore the stated goals of the implementation of the system should take into account the development strategy of the enterprise. The strategic goals of the enterprise under discussion are presented in Figure 4. All the goals included in the pyramid are related to the improvement of the efficiency and profitability of the company and with the streamlining of the information flow among the individual divisions of the company. At the top of the pyramid, the main goal of the company, that is, the maximization of its value, is located. The lower the level, the smaller the importance of the individual goal for the realization of the strategy of the entire enterprise.

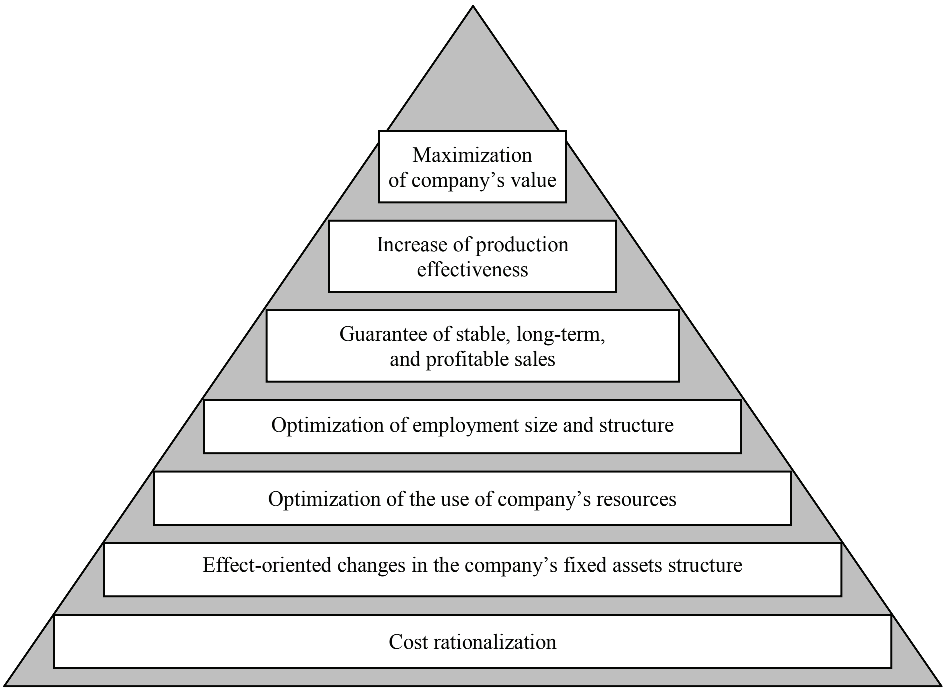

Figure 4. Pyramid of strategic goals

Source: Wieszała [2009].

As regards strategic goals, the enterprise has defined several detailed goals whose realization should be made easier by the ERP system. The main of them are: streamlining of information flow, increased control over the resources, uniformization of procedures, streamlining of key processes, enabling the introduction of project management methods, introduction of an integrated system for the management of human resources and skills, automation of order settlement, streamlining of the manufacturing logistics and transport management, computerization of the archives of certificates, attestations and manufacturing documentation, and the utilization of the e-commerce potential (in particular of B2B). Most of them result directly from the premises which caused the decision to implement ERP, as well as from the main problems related to the functioning of the enterprise.

The main goal of the system to be implemented is the streamlining of the information flow within the organization. The enterprise is the result of a merger and the companies comprising it belonged to various markets and have various experiences. It is necessary to create a platform bonding the companies together within the new organizational structure, as well as a flexible and extensive report system for the board of directors and the shareholders. The enterprise has divisions in three voivodeships, and for this reason the system has to ensure an adequate level of data integration and to enable information flow by means of an internet network.

The next group of goals is related to the issues of organization functioning. Ensuring control over the enterprise resources means streamlining of the management and planning processes and controlling all its resources, in particular: storing, supply, utilization of equipment and machinery as well as processes related to the finances of the enterprise. Streamlining of the basic processes of the enterprise means automation of some of time-consuming tasks related to administration, accounting, or human resources management. Procedures recorded in the system should service the largest possible scope of the activities of the enterprise, while being easy to monitor. The next goal, procedure standardization, is related to the main goal. Certain standard procedures have to be established when the new organization is being created, and adherence to them has to be based on the system. The chief asset of the enterprise analyzed is its ability to provide full project support, from planning, to manufacturing, to installation. This means that the system has to capable of supporting each project in such a way as to provide access to all the data related to the consecutive stages, by means of a central database.

The remaining goals are related to the expectations of the enterprise with respect to the system. Business-to-Business (B2B) is the totality of relationships between the enterprise and its partners , middlepersons, suppliers, distributors, points of sale and service shops. The use of this technique makes it possible to automate part of the communication with suppliers by means of the systems, and therefore to streamline the processes of the supply chain and to monitor the project realization. The next goal, partly related to the possibilities of B2B, is the management of manufacturing logistics and goods distribution, in particular, the management of transportation between the individual branches of the enterprise or between the enterprise and its customers. The management of human resources and skills is of particular importance when it comes to specialized tasks, such as welding or work at height, since they require special certifications and medical check-ups. The specific character of the enterprise requires gathering of all attestations and certificates for the individual construction elements. It is expected that it will be possible to automate and computerize the order repository management by means of the system.

3.3. Criteria for the selection of an ERP system

The main issue in the selection process is the establishment of the set of the estimation criteria for the individual variants. It should be large enough to encompass all relevant features of the variants analyzed, but not so large as to make the entire selection process difficult and to generate additional costs related to the longer duration of the analysis and a larger amount of information. Various sets of criteria for the ERP selection problem have been proposed in the literature; here we try to discuss only some of them to find the overall direction suggested by the authors.

Bernroider and Koch, in their paper on the selection of ERP systems for enterprises, pointed out the differences in the selection process depending on the size of the organization [Bernoider, Koch, 2001]. Everdingen, Hillegersberg and Waarts attach particular importance to such criteria as: adjustment to the business processes of the enterprise, flexibility, costs, ease of use, user-friendliness, implementation time, and functionality [Everdingen, Hillegersberd, Waarts, 2000]. According to the Epicor consultants, there are eleven key criteria for finding and selecting a solution satisfying the enterprise's expectations. They are: ability to support the enterprise in the future, solidity, expert knowledge as regards system replacement, elimination of implementation guesswork, good knowledge of the industry in question, utilizing the development of technology for the good of the enterprise, guaranteed scalability, high level of technical support and service, integrity and dedication, and guarantee of return on investment.

In the context of solutions for small and middle-size enterprises, Rao has suggested taking into account in the assessment process: cost analysis, market sector in which the vendor specializes, proximity of the vendor, as well as the development abilities of both the technology and the system [Rao, 2000]. Verville and Halingten have grouped the criteria into three groups: vendor assessment criteria, technical criteria of the system, and criteria for the system functionality assessment [Verville, Bernadas, 2005]. Similarly, Neves, Fenn and Sulcas also divided the criteria into three main groups. Within these groups they have defined 21 detailed criteria to be taken into account by the enterprise in the analysis. Among them are: the number of implementations done by the vendor on the local market, the assessment of his market position, adaptation to the functional requirements of the organization, and capacity for development [Das Neves, Fenn, Sulcas, 2004].

Most papers mentioned here suggest that the assessment of software vendor plays a great role in the system selection process. The most often repeated criteria, other than costs, are: flexibility, ability to adapt the system to the business process specific for the organization, user-friendliness, implementation time, and development perspectives. Vendor criteria encompass the assessment of his market position and quality of cooperation, and the assessment of the services offered by the vendor.

Using the papers cited, the selection criteria discussed in this paper have been divided into three groups: technical-technological criteria, system functionality criteria, and vendor assessment criteria. Additionally, detailed criteria of assessment have been established within each group.

The first group consists of functional criteria, defining the functions of the system which are directly perceived by the user. This group includes mostly criteria related to the functionality, flexibility, and ease of use of the system.

The scope of functionality determines the detailed abilities of the system and the range of activities of the enterprise which the system can support. It is assumed that the functions of the system overlap as much as possible with the business processes of the enterprise. This criterion estimates the extent to which the system satisfies the enterprise's requirements. In the context of the enterprise analyzed this is the support for individual production, integration of CAD-based project systems, and a project management module.

A separate criterion of strategic adaptability has been singled out from the functionality criterion. It estimates the ability to satisfy future needs of the enterprise, resulting from the realization of its strategy.

By system flexibility we mean its ability to adapt to the existing market situation. Also, the system should be scalable, that is, it should be possible to install only those components which will actually be used; on the other hand, it should allow for the development of the system as the organization grows. System flexibility is understood also as its capacity for introduction of structural changes, so as to be able to adapt the solutions to the enterprise's needs as fully as possible. The system should also ensure smooth integration with other applications, in particular with industry-specific solutions. An advantage of the system is also its self-dependence as regards both hardware and platform, thanks to which the enterprise can freely use computer-based solutions.

A user-friendly system is a system easy to use and not requiring a long learning process of each individual function. In this criterion, particular attention has been paid to the ergonomics of the interaction with the system, easy adaptation to the needs of the given user (for instance, through menu personalization or interface look and feel), adherence to generally adopted standards (for instance, with regard to document appearance), and intuitiveness.

Features such as a clear graphic interface, well-written user manual, on-line help with expert assistance, or interactive on-line courses encourage users to accept the system.

The last criterion in this group concerns data security. The data gathered constitute a valuable resource of the enterprise; their loss can cause a significant deterioration of its situation. Within this criterion, we will analyze, first of all, security levels, security functions, encrypting, and ability to manage permissions.

Another group consists of technical and technological criteria, which are not perceived directly by the average user, but translate into many features that determine such system abilities as flexibility, processing efficiency, openness, scalability.

The first criterion in this group is system architecture. This criterion assesses the technology used in building the system. Here are assessed, among other things, methods of data management, communication protocols used, supported device interfaces, and overall system architecture, including network capacities, built-in procedures for multi-division enterprise management, capacities for parameterization and for user influence on the functioning of the system.

The criterion of adaptation to the technological needs of the enterprise assesses the extent to which the technology used by the system will support the functioning of the enterprise. Only actual needs of the enterprise are analyzed, to avoid unnecessary involvement of too advanced or obsolete technology. This criterion reflects the criterion of the strategic adaptability (from the group of functional criteria). The technology chosen by the enterprise should be capable of supporting the enterprise at each stage of the realization of the strategy, both now and in the future.

The fundamental condition of the usability of the system is its stability; an ERP system integrates the entire information system of the enterprise, and thus any dysfunction can cause significant losses. It is easy to imagine a situation in which a shortage of components for manufacturing occurs or an invoice is incorrectly entered.

The innovativeness criterion should assess how the given system differs from others as regards the use of new solutions which increase its output, functionality or flexibility.

The last group consists of criteria assessing system vendors. The fundamental criterion in this group is the assessment of the market position of the vendor. It reflects the market strength of the vendor and indicates the popularity of the solutions proposed by him. The better the vendor's position, the higher the probability that his system will satisfy the highest requirements and that it will be capable of future development.

The cost criterion is still one of the most important factors influencing the decision to purchase a given system. It is essential to take into account the actual cost of the system, that is the costs of the license, technical infrastructure, consultants, training, as well as the costs of new modules, upgrades, and updates.

The next criterion – the organizational and financial abilities of the vendor – assesses the contractor's stability on the market. The implementation of an ERP system requires a significant organizational and financial involvement of both parties. That is why the financial situation of the contractor is a very important factor in the selection of an ERP system. It should be kept in mind that a system will be used at least five years, and therefore one should have contractor's support ensured for that period. It is also important to analyze the organizational capabilities of the vendor. A small vendor will not be able to provide adequate support for a large client and vice versa. When analyzing implementation in our enterprise, we should consider a large vendor with an adequate base of highly qualified consultants who will be able to implement the system efficiently and quickly.

An oft-touched upon issue is the ensuring of system integration, security, and stability. For that reason, attention should be paid to the support by the vendor. Availability of the consultants and assistance with problem solutions can be critical success factors of the entire implementation. Other services provided by vendors are also assessed within this criterion. Such services are, for instance, assistance with purchase of specialized equipment and its installation. If the enterprise decides to use outsourcing, the vendor should also help with finding trusted partners. Often, software vendors can help their customers in the search of financing for the system.

The criterion of implementation time and methodology allows to assess the implementation method offered by the vendor. Almost every larger company specializing in the implementation of integrated management systems has its own methods and schedules of implementation depending on the experience of its employees, the number of system modules, the scope of implementation, expenses for training, and infrastructure.

All the criteria described here are shown in Table 1 together with symbols used in later calculations.

4. A Numerical example

The presented method is explained on the example of choosing an ERP system for a hypothetical small enterprise whose main activity is manufacturing.

Step 1. After the formation of the project team and the collection of needed data, problem analysis based on method proposed in part 2, was conducted. The results of the analysis are important for the next steps.

Step 2. Based on the analysis performed in step 1, three clusters, with 17 criteria are proposed; they are presented in Table 1.

Table 1

Criteria of the proposed ERP selection model

Cluster	Name	Symbol
Functionality Features	Functionality	F
	Strategic Alignment	SA
	FleXibility	FX
	User Friendliness	UF
	Safety	S
Technical Features	System aRchitecture	SR
	Technical Alignment	TA
	Solution Innovation	SI
	Reliability	R
Vendor Factor	Market Share	MS
	Total Cost	TC
	Financial and Organizational Capabilities	FOC
	Service Support	SS
	Implementation Time	IT

Step 3: The few ERP systems available on the Polish market are presented in Table 2. The proposed method will be used to choose the optimal system.

Table 2

ERP systems available on the Polish market

No.	Name	Manufacturer/Vendor	Main Field of Usage	Usage References
1	BAAN IV c4	INFOR, USA/ BEELC Poland	Manufacturing (Aerospace, Automotive, Shipbuilding) Services (Financial Services, Health-care, Insurance, Telecommunications) Distribution (Transportation & Logistics, Electrical, Industrial)	More than 13 000 customers in over 90 countries, a few companies in Poland
2	IFS Applications	IFS / IFS Industrial and Financial Systems Poland Sp. z o.o.	Small & Medium Size Enterprises (Special solutions for Construction Companies)	Many in over 46 countries also many in Poland
3	IMPULS 5	BPSC SA, Poland	Small & Medium Size Enterprises (Production Companies, Automotive Industry, Wood and Furnish Industry, Food Industry, Cloth Industry, Public Utility Companies, Distribution Companies, Construction Companies, Research and Education Institution)	More than 300 customers, mainly in Poland
4	SAP	SAP, Waldorf Germany	All types of business: Financial and Public Services: Banking, Defense & Security, Healthcare, Higher Education & Research, Insurance, Public Sector Manufacturing & operations: Aerospace & Defense, Automotive, Chemicals, Consumer Products, Industrial Machinery & Components, Engineering, Construction & Operations	More than 92,000 customers in over 120 countries, many companies in Poland
5	VANTAGE	EPICOR, USA / Epicor Software Poland Sp. z o.o.	Mainly Medium & Large Size Production, Trade / Service Companies	A few companies in Poland

Step 4: Based on usage references on the Polish market and field of usage – small enterprises – three systems have been chosen for the short list: IFS Applications (IFS), IMPULS 5 (IM5) and SAP (SAP).

Step 5: A dependence matrix has been defined by the project team. Figure 5 shows the ANP interaction network for the selection of the most suitable ERP system software, created using the dependence matrix presented in Table 3.

Table 3

Dependence matrix

	F	FX	S	SA	UF	R	SI	SR	TA	FOC	IT	MS	SS	TC	IFS	IM5	SAP
F	0	1	1	1	0	0	1	0	1	0	1	0	0	1	1	1	1
FX	1	0	0	1	1	0	0	1	1	1	1	0	0	1	1	1	1
S	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1
SA	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1
UF	0	1	1	0	0	1	1	0	0	1	1	0	0	0	1	1	1
R	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1
SI	0	1	1	0	0	1	0	0	0	1	0	0	0	1	1	1	1
SR	1	1	1	1	0	1	1	0	1	0	0	0	0	1	1	1	1
TA	1	1	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1
FOC	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1
IT	0	1	0	0	1	0	0	0	0	1	0	0	0	1	1	1	1
MS	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
SS	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1
TC	1	0	0	0	0	0	1	0	0	1	1	1	1	0	1	1	1
IFS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
IM5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
SAP	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0

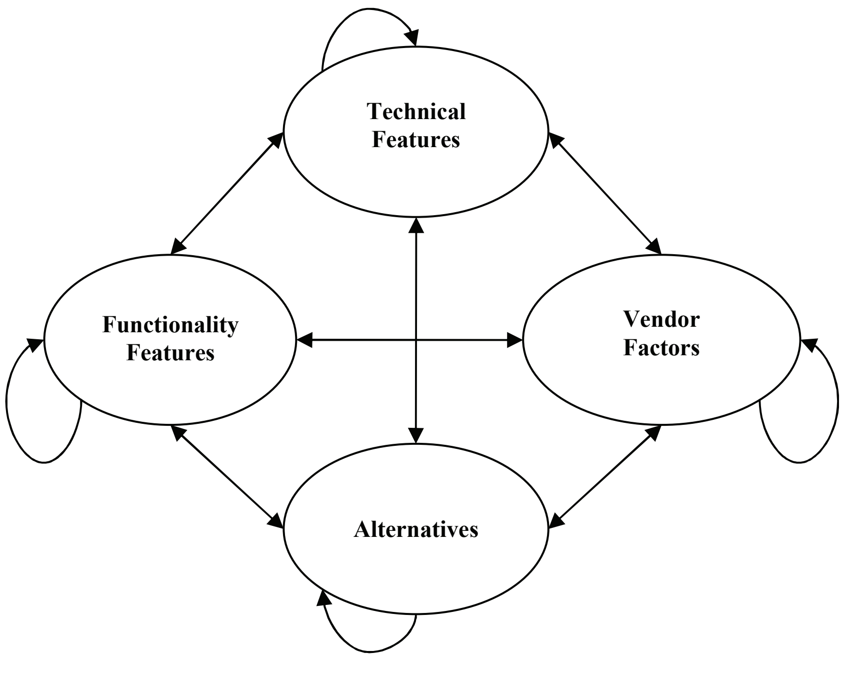

Figure 3. ANP model for the selection of a suitable ERP system

Step 6: In this step criteria and alternatives are compared with respect to the selected criteria. Due to limited space in this paper this process is shown for one criterion only, namely Functionality (F) (Tables 4 to 8).

First of all, based on expert judgments, Implementation Time (IT) are compared with Total Costs (TC) with respect to F. For example, one of the experts evaluates that TC is six times more important than IT, as shown in Table 4. Based on this information the parameter δ_j is computed and used for computing the normalized matrix *B* (Table 5) with respect to the relation:

$$\beta_{ij} = \frac{a_{ij}}{\delta_j}$$

Table 4

Computing δ_j

F	IT	TC
IT	1	0,1667
TC	6	1
$\delta_j = \sum_{i=1}^{n} a_{ij}$	7	1,1667

Table 5

Computing the normalized matrix $B = [\beta_{ij}]_{i,j=1\ldots n}$

F	IT	TC
IT	0,1429	0,1429
TC	0,8571	0,8571

Now the vector of priorities w_i can be computed from the equation:

$$w_i = \frac{1}{n}\left(\sum_{j=1}^{n} \beta_{ij}\right)$$

The results are presented in Table 6.

Table 6

Computing the vector of priorities w_i

F	$w_i = \frac{1}{n}\left(\sum_{j=1}^{n} \beta_{ij}\right)$
IT	0,1429
TC	0,8571

Next the alternatives are pairwise compared with respect to each criterion in our example in Table 7 with respect to Functionality. In this Table Consistency Index (*CI*) is also computed.

Table 7

Comparing F element in Alternative's cluster

F	IFS	IM 5	SAP	w_i
IFS	1	1	2	0,4000
IM 5	1	1	2	0,4000
SAP	0,5	0,5	1	0,2000
$\lambda_{max} = \frac{1}{n}\left(\sum_{i=1}^{n} \frac{(Aw)_i}{w_i}\right)$ $CI = \frac{\lambda_{max} - n}{n-1}$				0,0000

As F depends on Flexibility (FX), Safety (S) and Strategic Alignment (SA), it must be also compared in Feature cluster (Table 8).

Table 8

Comparing F element in Functionality Feature cluster

F	FX	S	SA	w_i
FX	1	5	4	0,6738
S	0,2	1	0,3333	0,1006
SA	0,25	3	1	0,2255
$\lambda_{max} = \frac{1}{n}\left(\sum_{i=1}^{n} \frac{(Aw)_i}{w_i}\right)$ $CI = \frac{\lambda_{max} - n}{n-1}$				0,0825

Step 7: Based on the priority vectors computed in step 6, the Initial Supermatrix is constructed. This Supermatrix is shown in Table 14. The values computed in this example are in the first column.

Step 8: The Weighted Supermatrix is computed. Since all clusters depend on each other, as shown in Figure 3, we must compare pairwise all clusters with respect to each other. The comparisons are shown in Tables 9 to 12.

Table 9

Comparing clusters with respect to Alternatives

Alternatives	Functionality Features	Technical Features	Vendor Factors	Alternatives	Priorities
Functionality Features	1,00	3,00	4,00	6,00	0,5609
Technical Features		1,00	1,00	3,00	0,1898
Vendor Factors			1,00	3,00	0,1783
Alternatives				1,00	0,0710
				CI	0,0172

Table 10

Comparing clusters with respect to Vendor Factors

Vendor Factors	Functionality Features	Technical Features	Vendor Factors	Alternatives	Priorities
Functionality Features	1,00	1,00	0,33	1,00	0,1728
Technical Features		1,00	0,33	0,33	0,1300
Vendor Factors			1,00	1,67	0,4331
Alternatives				1,00	0,2640
				CI	0,0432

Table 11

Comparing clusters with respect to Functionality Features

Functionality Features	Functionality Features	Technical Features	Vendor Factors	Alternatives	Priorities
Functionality Features	1,00	0,33	4,00	3,00	0,2542
Technical Features		1,00	6,00	6,00	0,5790
Vendor Factors			1,00	1,00	0,0808
Alternatives				1,00	0,0860
				CI	0,0172

Table 12

Comparing clusters with respect to Technical Features

Technical Features	Functionality Features	Technical Features	Vendor Factors	Alternatives	Priorities
Functionality Features	1,00	2,00	5,00	3,00	0,4539
Technical Features		1,00	4,00	5,00	0,3531
Vendor Factors			1,00	0,50	0,0752
Alternatives				1,00	0,1178
				CI	0,0609

The Weighted Supermatrix is shown in Table 15.

Step 9: The Limit Supermatrix G is computed from the formula

$$\frac{1}{n}\sum_{k=1}^{n} W^k = G$$

The result is shown in Table 16.
Finally we receive priorities shown in Table 13.

Table 13

Synthesis for the alternatives

Alternatives	Derived Priorities	Priorities (Normalized)	Rank
IFS	0,0448	0,3035	2
IM5	0,0651	0,4415	1
SAP	0,0376	0,2550	3

Summary and Conclusions

The selection of a suitable ERP system, in particular for a small enterprise, is a strategic decision which should be carefully prepared and organized. In this paper we propose the Analytic Network Process model for ERP system selection. The ANP model can provide a more accurate mechanism to better understand the nature of trade-offs between various criteria than standard selection methods, because it is capable of dealing with all kinds of feedback and dependence, when modeling a complex decision environment [Rashid Hossain, Patrick, 2002].

If standard selection models are applied, managers might base their decisions on a subset of important criteria only, without understanding their relative importance and interactions. The major advantage of this approach is that it assists them to approach the selection comprehensively. Furthermore, our model is flexible, easy to understand, and does not require an increase of IT costs.

Although the model proposed provides a comprehensive framework to guide the management of any company, the methods proposed have limitations. First, the model does not consider all possible clusters, elements and their interactions. Depending on the decision-making team, additional factors and interactions, within and between decision elements and alternatives could be added. However, the additional factors and their interactions require additional time and effort necessary for completion of such a model. In this case, the number of pairwise comparisons required would be quite high. Second, the model is very dependent on the weightings provided by decision makers. While this model effectively incorporates qualitative and quantitative measures into the evaluation process, its efficacy depends on the accuracy and the value of judgment provided by the decision making team.

In the example presented, the reduction of the list of alternatives plays an important role. With a longer list numerical problems have been observed. It is best to reduce the list of alternatives to three elements.

The ideas presented in this paper can be applied to real-life selection problems. The goal of future research is to improve the ANP model and to prove usefulness of this method by applying the ANP-based models to different companies operating in various industries. A comparison of the model proposed here with other tools and a different ANP base model should be investigated.

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Appendix

Table 1

Initial Supermatrix

	F	FX	S	SA	UF	R	SI	SR	TA	FOC	IT	MS	SS	TC	IFS	IM5	SAP
F	0,0000	0,3333	0,0000	1,0000	0,0000	0,0000	0,0000	0,2500	0,2756	0,0000	0,0000	0,2180	0,0000	1,0000	0,2031	0,1169	0,4804
FX	0,6738	0,0000	0,0000	0,0000	0,5000	0,0000	0,5000	0,2500	0,1412	0,0000	0,8333	0,5153	0,0000	0,0000	0,1276	0,2122	0,2402
S	0,1007	0,0000	0,0000	0,0000	0,5000	1,0000	0,5000	0,2500	0,0000	0,0000	0,0000	0,0603	0,0000	0,0000	0,0535	0,0587	0,1146
SA	0,2255	0,3333	0,0000	0,0000	0,0000	0,0000	0,0000	0,2500	0,4827	0,0000	0,0000	0,1199	0,0000	0,0000	0,5270	0,3697	0,1098
UF	0,0000	0,3333	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,1006	0,0000	0,1667	0,0865	1,0000	0,0000	0,0889	0,2425	0,0549
R	0,0000	0,0000	1,0000	0,0000	1,0000	0,0000	1,0000	0,3333	0,0000	0,0000	0,0000	0,2581	0,0000	0,0000	0,1704	0,1851	0,0640
SI	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,3333	0,0000	1,0000	0,0000	0,1076	0,0000	1,0000	0,0724	0,1163	0,1005
SR	0,0000	0,5000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,1896	0,0000	0,0000	0,3418	0,2404	0,5731
TA	1,0000	0,5000	0,0000	1,0000	0,0000	0,0000	0,0000	0,3333	0,0000	0,0000	0,0000	0,4448	0,0000	0,0000	0,4154	0,4582	0,2624
FOC	0,0000	0,3333	0,0000	0,0000	0,0000	0,0000	0,5000	0,0000	0,0000	0,0000	0,8571	0,2175	0,0000	0,2500	0,2000	0,1135	0,2728
IT	0,1429	0,3333	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,1237	0,0000	0,2500	0,2000	0,2054	0,1327
MS	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2500	0,2000	0,0868	0,4923
SS	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2000	0,0000	0,0894	0,0000	0,2500	0,2000	0,2302	0,0650
TC	0,8571	0,3333	0,0000	0,0000	0,0000	1,0000	0,5000	1,0000	1,0000	0,8000	0,1429	0,5694	0,0000	0,0000	0,2000	0,3641	0,0372
IFS	0,4000	0,0936	0,3108	0,5469	0,2493	0,1958	0,1634	0,2403	0,4000	0,3108	0,1220	0,2403	0,1311	0,2583	0,0000	0,6667	0,8571
IM5	0,4000	0,6267	0,4934	0,3445	0,5936	0,4934	0,2970	0,2098	0,4000	0,1958	0,6483	0,2098	0,6608	0,6370	0,1250	0,0000	0,1429
SAP	0,2000	0,2797	0,1958	0,1085	0,1571	0,3108	0,5396	0,5499	0,2000	0,4934	0,2297	0,5499	0,2081	0,1047	0,8750	0,3333	0,0000

Table 2

Weighted Supermatrix

	F	FX	S	SA	UF	R	SI	SR	TA	FOC	IT	MS	SS	TC	IFS	IM5	SAP
F	0,0000	0,0847	0,0000	0,2765	0,0000	0,0000	0,0000	0,1135	0,1934	0,0000	0,0000	0,0377	0,0000	0,1728	0,1139	0,0656	0,2695
FX	0,1713	0,0000	0,0000	0,0000	0,1383	0,0000	0,2270	0,1135	0,0991	0,0000	0,1655	0,0891	0,0000	0,0000	0,0716	0,1190	0,1347
S	0,0256	0,0000	0,0000	0,0000	0,1383	0,7017	0,2270	0,1135	0,0000	0,0000	0,0000	0,0104	0,0000	0,0000	0,0300	0,0329	0,0643
SA	0,0573	0,0847	0,0000	0,0000	0,0000	0,0000	0,0000	0,1135	0,3387	0,0000	0,0000	0,0207	0,0000	0,0000	0,2956	0,2074	0,0616
UF	0,0000	0,0847	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0706	0,0000	0,0331	0,0149	0,3957	0,0000	0,0499	0,1360	0,0308
R	0,0000	0,0000	0,8706	0,0000	0,6299	0,0000	0,3531	0,1177	0,0000	0,0000	0,0000	0,0336	0,0000	0,0000	0,0323	0,0351	0,0122
SI	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,1177	0,0000	0,1572	0,0000	0,0140	0,0000	0,1301	0,0138	0,0221	0,0191
SR	0,0000	0,2895	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0247	0,0000	0,0000	0,0649	0,0456	0,1088
TA	0,5790	0,2895	0,0000	0,6299	0,0000	0,0000	0,0000	0,1177	0,0000	0,0000	0,0000	0,0579	0,0000	0,0000	0,0789	0,0870	0,0498
FOC	0,0000	0,0269	0,0000	0,0000	0,0000	0,0000	0,0376	0,0000	0,0000	0,0000	0,4268	0,0942	0,0000	0,1083	0,0357	0,0202	0,0486
IT	0,0115	0,0269	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0536	0,0000	0,1083	0,0357	0,0366	0,0237
MS	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,1083	0,0357	0,0155	0,0878
SS	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,1047	0,0000	0,0387	0,0000	0,1083	0,0357	0,0410	0,0116
TC	0,0693	0,0269	0,0000	0,0000	0,0000	0,1163	0,0376	0,0752	0,1163	0,4189	0,0711	0,2466	0,0000	0,0000	0,0357	0,0649	0,0066
IFS	0,0344	0,0081	0,0402	0,0512	0,0233	0,0356	0,0192	0,0283	0,0728	0,0992	0,0370	0,0634	0,0792	0,0682	0,0000	0,0473	0,0608
IM5	0,0344	0,0539	0,0638	0,0323	0,0556	0,0898	0,0350	0,0247	0,0728	0,0625	0,1967	0,0554	0,3993	0,1682	0,0089	0,0000	0,0101
SAP	0,0172	0,0241	0,0253	0,0102	0,0147	0,0566	0,0635	0,0648	0,0364	0,1575	0,0697	0,1452	0,1258	0,0277	0,0621	0,0237	0,0000

Table 3

Limit Supermatrix

	F	FX	S	SA	UF	R	SI	SR	TA	FOC	IT	MS	SS	TC	IFS	IM5	SAP
F	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928	0,0928
FX	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619	0,0619
S	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167	0,1167
SA	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921	0,0921
UF	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341	0,0341
R	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373	0,1373
SI	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179	0,0179
SR	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282
TA	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448	0,1448
FOC	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216	0,0216
IT	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151	0,0151
MS	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127	0,0127
SS	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143	0,0143
TC	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630	0,0630
IFS	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	0,0448	**0,0448**
IM5	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	0,0651	**0,0651**
SAP	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	0,0376	**0,0376**

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