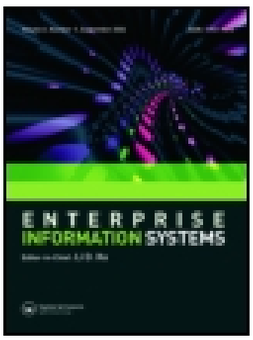

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Selection of enterprise resource planning software using analytic hierarchy process

Ricardo M. Czekster[a], Thais Webber[a], Alessandra H. Jandrey[a] and César Augusto Missio Marcon[b]

[a]Department of Computer Science, University of Santa Cruz do Sul, Santa Cruz do Sul, Brazil; [b]Faculty of Informatics, PUCRS University, Porto Alegre, Brazil

ABSTRACT

Selecting ERP (Enterprise Resource Planning) software is crucial to enhance productivity because it provides high-quality services for end users. The choice of an ERP is a problem that should undertake deeper scrutiny. For example, several criteria are usually present, having different tradeoffs. Analysts and managers, when deciding which ERP to acquire, have key considerations to address when facing the myriad of available software suites with market presence. Multicriteria modelling are used to help decision makers select ERPs and one commonly used technique for helping the process of addressing such problems is Analytic Hierarchy Process (AHP). Our work have surveyed the literature on selection of ERP and we have discovered that acquisition and monthly costs, ERP reputation and references, level of support and training, deployment experience, ERP's feature set, easiness of use, efficiency and reliability, and maintainability are key criteria. We have used those criteria to create an AHP model for deciding the best one according to judgements of importance. The focus of our work is directed for small and medium organizations. We have created a model for ERP selection of a healthcare facility and computed numerical results using pairwise comparisons and group decision-making by selected managers according to their expertise.

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AHP; multicriteria decision methods; enterprise resource planning

Introduction

Financial growth and profit pressure companies to acquire information systems that encompass the totality of their business processes, i.e., human resources, procurement, logistics, and several other departments. *Information Technology* (IT) expenses are increasing throughout the years, as enterprises are aware of the value they provide when enhancing operations and reducing costs. Companies frequently use such systems, commonly referred as *Enterprise Resource Planning* (ERP) software, aiming for integration and organization of complex business processes. Examples of industries that have adopted ERP with interesting outcomes are logistics/distribution companies, manufacturing (in general), education, construction, healthcare, and telecommunications, to cite a few.

CONTACT César Augusto Missio Marcon cesar.marcon@pucrs.br Faculty of Informatics, PUCRS University, Ipiranga, 6681, Porto Alegre, Brazil

ERPs were first implemented in 1990 as a tool to organize, standardize, and integrate processes aiming to raise productivity and efficiency levels due to a centralized information scheme (i.e., all relevant data is located at the same place), easily available to management. So, different stakeholders could visualize and access information systems in ERPs, at any time, aiding better decision-making and resource management (Kanchana and Sri Ranjini, 2018).

ERP is crucial for companies that want to improve information diffusion and knowledge management especially if classified as a *Small and Medium Enterprise* (SME), as thoroughly discussed by Antoniadis et al. (2015). The choice of an ERP must match the organization's objectives; i.e., it should offer relevant features and cost/benefits without financially impairing the company (Rajan and Baral 2015). An ERP encompasses dimensions other than only its functionalities. For instance, Antonova and Georgiev (2019) have deeply discussed the effect of security in ERP and its components since they are layers that interact and should be considered in conjunction.

More expensive ERPs are usually not aligned to the investment amount the enterprise may spend in terms of budget; so, options without as many features should be considered. Such possibilities when choosing the best ERP software mandate the use of a *Multicriteria Decision Method* (MCDM) (Brans and De Smet, 2016; Mardani et al. 2015; Saaty and Ergu 2015; Greco, Figueira, and Ehrgott 2016; Gonçalves et al. 2018). The idea is to devise a model having competing attributes, quality characteristics (e.g., intangibles), and tradeoffs among criteria/alternatives. This model is then subjected to a software tool that ranks possible alternatives (i.e., the decision).

It is worth mentioning that AHP was one of the first MCDM based on hierarchies for quantitative decision-making involving simple pairwise comparisons among criteria and alternatives. The technique evaluates relative importance among criteria and performs judgements on comparisons to yield a ranking consisting of the preferred selection (Saaty 1990). This work focuses on decision models that have used AHP, and available software are PriEsT (*Priority Estimation Tool*), SuperDecisions (Liu et al. 2003), Expert Choice (Ishizaka and Labib 2009), AHP-OS (Goepel 2018), and Decisor (Czekster et al. 2019) to name a few available choices. AHP is broadly used for a wide range of decision-making, from problems arising in companies (Widiantoro 2017; Balubaid and Alamoudi 2015; Wu et al. 2018), supplier selection (Nydick and Hill 1992; Barbarosoglu and Yazgac 1997; Ho, Xu, and Dey 2010; De Felice et al. 2015), to governance (Mahalik 2010), among others.

Our objective here is to survey the literature on ERP decision-making using multicriteria decision methods and create a model that may be used in other contexts, where managers could input a different set of judgments according to their setting. We aim to help the decision-making process in choosing the best ERP for a medium-sized enterprise, a problem that does incur due to the importance of having reliable software in daily operations. As research questions, we are interested in answering the following: *'What are the most important criteria when selecting an ERP for medium-sized enterprises?'* and also *'Which multicriteria model and methods should managers and stakeholders use to help them determine the best ERP according to a need of the company?'*.

The contribution of this work is two-fold: firstly, we surveyed the literature acquiring analysis reports of practical experience of managers to present the most used criteria when managers choose ERP for small and medium-sized enterprises worldwide.

Secondly, using this knowledge, an AHP model is proposed with criteria judgements based on expert opinions, helping the selection of an ERP system. We present a case study for an ERP selection of a Brazilian healthcare facility discussing criteria pairwise comparisons and evaluations combined with specific software options.

The work is organized as follows. Section 2 highlights related work and Section 3 presents AHP's method. Section 4 discusses the proposed set of key criteria for ERP selection, and in Section 5, the AHP model is developed and analysed using the knowledge of experts in healthcare assistance sector. In Section 6, we present the main implications of the approach, some final considerations and future works.

2. Decision-making and the analytic hierarchy process

The act of deciding is crucial for companies that are willing to remain competitive in demanding markets. Managers should decide based on available information at hand, in the strict timely fashion, avoiding monetary losses and other stressful aspects. It is common for any decision problem to cope with several criteria and alternatives. In this context emerges *Multicriteria Decision Methods* (MCDM), which aims to model complex decision problems capturing and addressing both qualitative and quantitative characteristics. It helps to assign numerical values to intangible aspects inherent to decisions, estimating better or worst options, having difficult cost and benefits relationships (Belton and Stewart 2002; Greco, Figueira, and Ehrgott 2016).

Hard to cope, difficult, or complex decision problems are characterized by aspects, such as (i) presence of multiple attributes; (ii) intangible measures; (iii) conflicts among criteria; (iv) incommensurable units, i.e., each attribute have a different unit or scale; and (v) alternative selection, meaning that one should be able to conclude by the end of the analysis, choosing one option over the others.

The literature on this subject is vast, as several models and methods have been defined and researched throughout the years. For example, known current methods with broad acceptance by the decision-making community are TOPSIS (*Technique for Order of Preference by Similarity to Ideal Solution*) (Hwang and Yoon 1981), ELECTRE (*ELimination and Choice Expressing REality*) (Roy 1990; Figueira, Mousseau, and Roy, 2016), MAUT (*Multi-attribute Utility Theory*)/MAVT (*Multi-attribute Value Theory*) (Dyer et al. 1992; Dyer 2005), VIKOR (*VIseKriterijumska Optimizacija I Kompromisno Resenje, i.e., Multicriteria Optimization and Compromise Solution*) (Opricovic and Tzeng 2004), AHP (*Analytic Hierarchy Process*)/ANP (*Analytic Network Process*) (Saaty 1990; Saaty and Vargas 2006), PROMETHEE (*Preference Ranking Organization METHod for Enrichment of Evaluations*) (Brans, Vincke, and Mareschal 1986), and BWM (*Best Worst Method*) (Rezaei 2015), to cite a few.

In this paper, the AHP method was chosen due to its simple modelling primitives and straightforward analysis features for decision-making. The basic idea is to operate with a trinity known as *Objective-Criteria-Alternatives*, i.e., the modeller chooses one clear decision problem under his scope, then he considers the most important criteria (often no more than seven more or less two, according to the seminal work on cognitive load performed by Miller (1956) with interesting implications in decision theory), and then the possible alternatives (two or more). After this definition (Saaty, 1991), the modeller should perform the pairwise comparisons among criteria, and per criteria,

Table 1. AHP's fundamental scale according to Saaty (1977).

Scale	Definition	Observation
1	Same importance, indifference	Both components contribute equally towards the objective
3	Small importance one over another	One element is slightly favoured with respect to (W.R.T.) the other
5	Considerable importance, essential	One characteristic is highly important W.R.T. the other
7	High importance	One choice is strongly more important W.R.T. the other in comparison, dominating the other
9	Highest importance, absolute	Highest importance between two elements, with high level of confidence of its relevance
2,4,6,8	Intermediate values among the scale	A reasonable compromise between two characteristics
Reciprocals	If a value at position [i,j] has value over zero, then at position [j,i] should have assigned 1/value, i.e., its reciprocal	The reciprocals values cause the model to have certain equilibrium W.R.T. the elements
Rational values	One could derive rational values as well	Rational numbers are used when different scales are considered

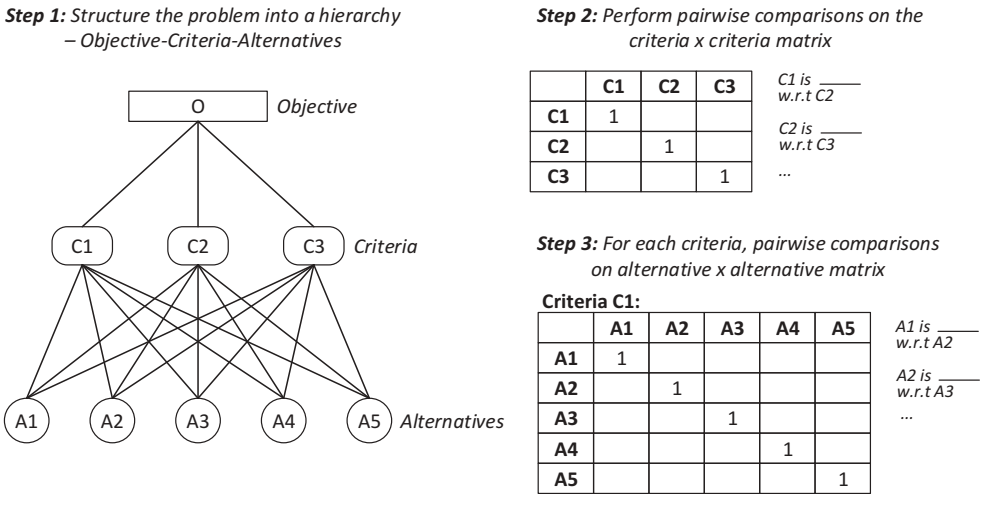
the comparisons among alternatives. This corresponds to the judgements performed by the decision makers, stipulating the intrinsic relations among criteria and alternatives. For this weighting, Saaty's seminal paper (Saaty 1977) suggests the use of a Fundamental Scale, presented in Table 1 as follows:

It is worth mentioning that other scales could be used (Ishizaka and Labib 2011), as discussed by some authors (Franek and Kresta 2014; Goepel 2019); however, due to simplicity, the Fundamental Scale is usually adopted without loss of generality.

There is a set of steps one must follow for creating an AHP model: (i) structuring the problem into a hierarchy having objective-criteria-alternatives; (ii) comparative judgments, i.e., pairwise comparisons, where one measures the relative importance of elements among each another, numerically weighing this difference for each possible pair, and; (iii) use a tool to compute weights and estimate the final global ranking, where a numerical procedure is performed to yield the ranking, i.e., the alternative that presents the highest priority for selection. Figure 1 shows the basic modelling process employed by AHP.

The model is complete when all pairwise comparisons are performed, then, one computes the eigenvector for the criteria x criteria matrix, called weight vector, and then the same process is conducted with the alternative x alternative matrices (one per criterion). Those two vectors go through a series of numerical computations where the method yields the alternative ranking; i.e., suggesting the preferred alternatives order according to the judgements (Saaty 1990; Saaty and Vargas 2006; Goepel 2019; Czekster et al. 2019).

AHP is broadly used for decision-making, such as environmental planning (Mustajoki and Marttunen 2017), decisions as to where to build a desalination plant (Dweiri, Khan, and Almulla 2018), Supplier Selection Problem (Bruno et al. 2012; Dweiri et al. 2016; Ishtiaq, Khan, and Haq 2018), housing selection and choice (Jansen 2011), supply chain using MCDA/DMAIC Six Sigma tools and methodologies (Rehman et al. 2018), and reverse logistics service provider selection (Jain and Khan 2017), to name a few applications. AHP was also used to select fashion suppliers (Chan and Chan 2010), solid waste treatment (Samah, Manaf, and Zuki 2010), as



	C1	C2	C3
C1	1		
C2		1	
C3			1

	A1	A2	A3	A4	A5
A1	1				
A2		1			
A3			1		
A4				1	
A5					1

Figure 1. Basic AHP modelling showing hierarchy and pairwise comparisons.

well as supplier selection using a combination of different MCDM techniques such as ANP, TOPSIS and Linear Programming (LP) (Lin, Chen, and Ting 2011). Görener, Toker, and Ulucay (2012) showed a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis using AHP, and Vidal, Marle, and Bocquet (2011) have studied a combination of Delphi process (a qualitative based approach) and AHP to evaluate the complexity of projects. For an overview of AHP models and applications, we refer readers to a valuable body of work developed throughout the years (Vaidya and Kumar 2006; Saaty and Vargas 2012; Schmoldt et al. 2013; Sipahi and Timor 2010; Subramanian and Ramanathan 2012). Specifically for selecting ERP using AHP, the work of Perera and Costa (2008) has applied the AHP technique for a manufacturing industry, as well as Boonyaprasit and Yang (2010), explained earlier.

3. Related work

Related work was selected considering three main aspects: publication year (prioritizing researches over the past 15 years), number of citations by other researchers as well as similarity to our approach.

3.1 ERP selection factors according to company size

The importance of selecting the right ERP according to company's size aims to find a good fit, i.e., the right size and feature set for actual use. There is no point purchasing the most popular choice and then spend enormous amounts of money in deploying, training, and performing other activities, only to perceive that the users are exclusively accessing a small set of functions in the ERP. Such systems are crucial for attaining high productivity to ensure long-term success and profitability (Beheshti and Beheshti 2010).

Since we have analysed two Brazilian institutions and their ERP adoption, we have surveyed specific taxonomy to define size according to specific measures and characteristics, such as SEBRAE (*Brazilian Service to Support Micro and Small Enterprises*), BNDES (*National Bank of Economic and Social Development*). We also surveyed the European Commission, and the Business Statistics (European Commission 2019). Both SEBRAE and BNDES classify companies according to total annual revenue and employee number, splitting into two segments: commerce and services. For the first segment, small businesses had up to 99 workers, medium from 100 to 499, and large from 500. For the service segment, small had up to 49 employees, medium from 50 to 99, and large from 100.

The European Commission takes into account revenue and total employees, classifying small companies as having up to 49 workers, medium up to 249 and large from 250 upwards. In the USA, there is more granularity divided across several branches for industry and services; we direct our readers to this reference for further information (SUSB 2019).

Udo (2000) has used AHP modelling to help the decision whether or not to outsource information technology provider discussing its strategic importance in evolving markets. Bernroider and Koch (2001) have discussed that company size does not significantly affect criteria selection, only on the judgement importance (the weight) assigned in comparisons. According to the authors, the main factors influencing the decision are flexibility, costs, and implementation issues of the ERP. They have investigated 116 large companies and 22 SMEs, providing a good overview of important factors that drive decisions. Also, the authors Laukkanen, Sarpola, and Hallikainen (2005) discussed issues related to ERP adoption identifying findings suggesting that small companies experience more knowledge constraints than their larger counterparts. Xu et al. (2008) have used AHP and fuzzy logic for selection of enterprise information systems for faster decision-making.

Since the decision of choosing the ERP for a company, many stakeholders are involved such as managers and IT departments. The direction taken by Ifinedo and Nahar (2007) consisted of looking at two groups, business managers and IT professionals, and study ERP success measures. The authors have found no significant statistical differences, except for vendor/consultant quality, deemed different for the two groups investigated. Leu and Lee (2017) present an interesting discussion on ERP integration with Six Sigma tools and methodologies. The objective was to propose a framework and apply it to manufacturing enterprise in Taiwan.

More recently, Haddara (2018) has discussed common criteria shared by large companies and how they are similar to SMEs. For instance, the author has mentioned important factors such as the ERP's feature set, reliability, compatibility, cost, supplier services, growth issues, and market reputation. The work also addresses other decision dimensions such as other several benefits and opportunities that may be relevant in a management point of view, not only looking at costs when selecting an ERP. Zach, Munkvold, and Olsen (2014) discussed ERP implementation for SMEs in contrast with large companies. They have studied four SMEs across the ERP life cycle, where they have discovered that ownership type and limited resources were the main factors that played significant influence.

3.2 Common ERP criteria in related research

The aim of surveying the literature is to address the state-of-the-art of business decisions concerning ERPs for SMEs. We have conducted a focused search on Scopus, Google Scholar and Science Direct, with input search strings such as ((‘multicriteria decision-making’ or ‘MCDM’ or ‘MCDA’ or ‘decision-making’) and (‘ERP’ or ‘Enterprise Resource Planning’) or ‘SME’ or ‘Small and Medium Enterprises’) on the past 15 years. We have filtered initial results to only those dealing with decision-making processes, i.e., those where the paper objective was to select an ERP using a multicriteria approach to decision-making. Then, we proceed by taking a more in-depth look at their main findings and results. Table 2 comments related work and most common selected criteria for choosing ERP software in many organizations.

It is noticeable the number of different views and key aspects when selecting ERP systems as the literature presents a considerable body of work and analysis options. For example, managers and decision makers are interested in supplier support and reputation, as well as possibilities for adding new features or customizations after the purchase. It is interesting to notice that cost does not play a fundamental role in the decision as to the best ERP system to adopt within the company. There is a preoccupation in acquiring a useful tool, the one that has the potential to yield the best efficiency and productivity for the company.

These selected authors have compiled data on criteria comparisons and alternatives using questionnaires and documents related to each alternative. The number of respondents varied for each related work as well as the support tool to calculate the results. The number of experts involved in these studies is also very interesting to evaluate for only a small number of domain specialists were *de facto* required for aiding the decision process in the case studies. This serves as an inspiration for SMEs that are wasting a huge amount of time in their current ERP, since they could investigate whether or not it would be best to keep training staff for the current software or it would be interesting to shift approaches and purchase another solution that may yield better outcomes soon.

4. AHP model for ERP selection

Our survey has revealed 40 distinct criteria; i.e., a challenging effort to devise an appropriate AHP model. In this kind of modelling, it is usually suggested to choose seven more or less two (7 more or less 2) criteria or alternatives, due to the inherent cognitive load required when considering such factors (Miller 1956; Sweller 1994). For data collection, we have applied an online questionnaire directed to domain experts (with different levels of expertise) and then select the most recurrent ones. Inspecting the results, we have deemed as sufficient the threshold of three out of seven criteria mentions, i.e., the same criteria appear in approximately one-third of all responses.

The first round of criteria analysis has yielded 19 criteria, which is a very high number to be inputted into an AHP model. As a second step, we have applied a qualitative approach for selecting criteria by grouping similar criteria together, i.e., those having analogous characteristics. This process resulted in ten criteria, which we have selected nine to build a sufficient and robust AHP model.

Table 2. Methods and criteria used for ERP selection in selected research papers.

Reference	Comments on work objectives and adopted criteria	Total Criteria	MCDM
Wei, Chien, and Wang Wang 2005)	**Select an ERP for an electronics company in Taiwan, China** Both, software factors and supplier characteristics are considered. For software, the authors selected total cost, development time (for improvements after acquisition), feature set, user-friendliness, flexibility, and reliability. For the supplier, the authors worked with experience, offered services, and reputation	9	AHP
(Haddara 2014)	**Study critical success factors in ERP adoption** The author has listed the feature set, technical requirements, costs, services and support, supplier reputation, reliability, compatibility, market share, integration, deployment methodology, and adherence to the company as major criteria	11	None
(Hamidi 2015)	**Select criteria and weights for an Iranian company** Two distinct criteria: Management Factors and Product Factors. Each one with a set of sub-criteria, for the first, implementation time, cost, vendor reputation, consultancy services, R&D capability. For the latter sub-criteria: interoperability, reusability, user-friendliness, flexibility, portability, functionality, reliability, usability, maintainability, and efficiency	15	*fuzzy*-AHP
(Cunha-Cruz et al. 2016)	**ERP selection in a Portuguese based company** Technical team capability, Coverage of the required functionalities norms/regulations, Vendor references/portfolio, Offered guarantees, Quality: Technical support, documentation, and consultancy services, Training services, Payment/financial terms, Vendor market share/scale, Implementation ability, Vendor financial conditions, OS compatibility, HW requirements, Database engine compatibility, Integration with other platforms, Source code accessibility, User friendliness, Costs: SW licensing, HW/infrastructure, integration/middleware, maintenance, software acquisition, and consultancy, Scalability/upgradeability, Stability/recovery capacity, Security issues, Customization	28	AHP
(Fathollahi et al. 2016)	**Select an ERP in Persia (Iran)** Technology (three subcriteria), Costs (three), Supplier (two) and Time (three)	11	AHP
(Armand and Roger 2017)	**ERP selection in Africa, using the socio-economic context and particular difficulties inherent to the region** Divided software into classes: Open Source; Proprietary; In-house; Outsourcing; Off-the-Shelf; On-Premise; Mobile and Cloud	5	AHP
(Motaki and Kamach 2017)	**Criteria selection for choosing the best ERP system** Authors opted to describe a list of Criteria and sub-criteria: *Adaptability* (compatibility with the enterprise business processes, technical constraints, system features, ability to integrate company platforms and data); *Financial* (Service/support cost, Product license, Implementation cost, Budget of the company); *Simplicity* (Ease of use, Ergonomic software, Complexity system); *Provider services* (Maintainability and Support from provider, Training); *Implementation* (Duration of ERP implementation; complexity of implementation; Successful references)	18	AHP

Table 3 relates researches and criteria, dividing the analysis by similar characteristics. Some criteria are marked as bold, representing that the selected reference set is discussed in several researches (four or more mentions).

We have grouped the criteria into three aspects according to their characteristics; i.e., general costs were grouped as 'Financial' issues, whereas all software related was categorized in 'Software' and those pertaining ERP's suppliers were assigned to the 'Supplier related' group. This was done only to organize criteria and enhance understandability. Inspecting Table 3 in detail, we have extracted key criteria that are useful in our AHP model proposition:

Table 3. Related criteria in researches.

Criterion		A	B	C	D	E	F	G	Total
Financial	**Acquisition and Maintenance cost**	✓	✓	✓	✓	✓	✓	✓	7
	Monthly cost		✓		✓			✓	3
	Payment and financial terms	✓			✓				2
Supplier related	Implementation time			✓		✓		✓	3
	Reputation and references on market	✓	✓	✓	✓	✓		✓	6
	Support	✓	✓	✓	✓			✓	5
	Business strategy alignment						✓	✓	2
	Documentation				✓				1
	Implementation experience	✓	✓		✓			✓	4
	Training	✓	✓	✓	✓	✓		✓	6
Software	Customization	✓			✓	✓			3
	System efficiency			✓	✓	✓			3
	Backup/restore capabilities				✓	✓			2
	Easiness of use	✓		✓	✓	✓	✓	✓	6
	Reliability	✓	✓	✓		✓			4
	Warranties	✓			✓				2
	Scalability				✓				1
	Portability			✓					1
	Security	✓			✓				2
	Flexibility	✓		✓					2
	System integration	✓	✓		✓			✓	4
	Feature set	✓	✓	✓	✓			✓	5
	Integration with other systems		✓	✓	✓				3
	Maintainability			✓		✓		✓	3
	Technical requirements		✓	✓	✓	✓	✓	✓	6

Refs. A: C-C., C-F., and Wang (2005); B: Haddara (2014); C: Hamidi (2015); D: Cunha-Cruz et al. (2016); E: Fathollahi et al. (2016); F: Armand and Roger (2017); G: Motaki and Kamach (2017)

(1) *Acquisition costs*: involves general costs such as those related to extra equipment purchases, licensing, and other related costs;
(2) *Monthly payments*: special training costs, support, and system maintenance;
(3) *Reputation and references on the market*: Haddara (2014) strongly advocates this measure, explaining its importance when choosing an ERP software because the system is expected to last a long duration;
(4) *Support & training*: aggregated services about the system, i.e., additional training and documentation, as well as support provided by the supplier;
(5) *Deployment experience*: this reflects directly on expected quality and reasonable time to solve issues in earlier versions (e.g., installing) of the ERP;
(6) *Feature set*: offered system functions, reflecting on the system's ability to improve efficiency and time to solve issues using the system;
(7) *Easiness of use*: involves user-friendly interface, smart menus, simple navigation, easy to use documentation, and updated information;
(8) *Efficiency & reliability*: users should be able to trust the system, and to perform tasks in a timely fashion;
(9) *Maintainability*: refers to the ability to correct defects or modifications quickly (e.g., conformance to new laws or general updates).

Many authors considered those nine criteria as crucial elements for choosing an ERP for a range of companies. It is worth mentioning that several researches have discussed that those criteria have decisively helped decision-makers to choose the best software option for ERP according to the company's needs.

4.1 Criteria judgements with an on-line questionnaire

We have divided the judgements assignment procedure into two phases: the first considered an online questionnaire and group decision-making (several stakeholders make judgements, then a geometric mean is calculated per comparison one for each inputted value). The second phase has determined the alternatives comparisons more qualitatively, i.e., interviews with selected stakeholders were conducted.

Before devising the model, we intended to reach a large audience of experts, grasping their opinions and views on the problem of selecting an ERP. So, we have devised an on-line questionnaire and targeted at experienced professionals and decision makers. The idea was to use AHP's fundamental scale and infer judgements for those criteria mentioned above. We have divided the questionnaire into 11 sections, where the first one has identified the respondent, instruction level, and experience level. Sections 2 through 10 of the questionnaire have asked stakeholders for the pairwise comparisons for those nine selected criteria, where they have chosen the importance of one criterion over all others, by answering simple questions such as *'Concerning X and Y, how much would you say that one influences the other?'* (X and Y are two specific criteria). Since there are nine criteria, the total number of pairwise comparisons needed for this phase is 36 (i.e., (9*9–9)/2 = 72/2 = 36). To ease the burden of too many comparisons for one specific criterion, we have divided the judgements in two, so only four comparisons were needed per criterion. Figure 2 explains this process, showing required comparisons for this study, where each Criterion (Cn) is confronted against other four criteria. It is

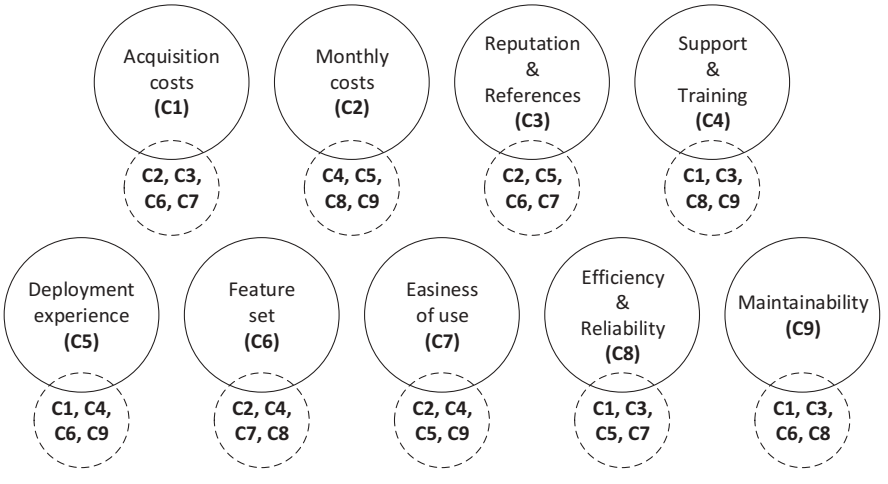


Figure 2. Pairwise comparisons for selected criteria in ERP decision-making.

Table 4. Profile analysis of the questionnaire's respondents.

Age profile		**Position**		**Gender**	
18 to 24 years	40%	Lecturer	6.67%	Male	46.67%
25 to 34 years	26.67%	Consultant	6.67%	Female	53.33%
35 to 44 years	33.33%	Analyst	13.33%		
		Assistant	20%	**Segment**	
Technological company		Manager	26.67%	Service	66.67%
Yes	33.33%	Senior manager	26.67%	Industry	33.33%
No	66.67%				
		Number of employees		**Location**	
Instruction level		Up to 49	33.33%	Brazil-RS	53%
M.Sc.	6.67%	50 to 99	13.33%	Brazil-PR	33%
High school	6.67%	100 to 499	13.33%	Brazil-SC	7%
Graduate	26.67%	500+	40%	USA	7%
Undergraduate (partial)	26.67%				
Undergraduate	33.33%				

worth mentioning that nine criteria are a large number of options to consider when using AHP as the main decision-making procedure, as stated earlier, due to the cognitive load required.

We have used *closed questions*, mapping Saaty's Judgement Scale to its textual counterpart, so respondents would find it easier to associate numbers to intangible characteristics. The questionnaire ended with an Open Question, asking whether or not some criteria should have been present, and what the respondent considered as necessary in ERP selection. We have sent the questionnaire link to at least 50 managers and decision makers for different companies, and 15 respondents have replied within three weeks. As shown in Table 4, they had different backgrounds and expertise level, as we have conducted a comprehensive profile analysis.

As noted by the table, there is a broad spectrum of professional types within our study, varying gender, working segment, company size, location (most of them are Brazilian companies), and company focus. This mix was deemed acceptable to our analysis because those are professionals that use any given ERP throughout the day and also during their job, so they know the key criteria as well as alternatives.

5. AHP model criteria judgements calculation

With the criteria and the judgements, it is possible to start the AHP modelling – the only missing information at this point is the pairwise comparisons for the alternatives per criterion. As stated earlier, we will address this issue qualitatively, i.e., doing interviews with domain experts, after detailing criteria x criteria analysis (Section 5.1).

We will now describe the methodology used to derive the actual judgement: we have compiled all answers and scales from the questionnaire, and we have considered using Group Decision-making. Therefore, for every value, we have applied the *Geometric Mean* as the literature on this subject suggests to be used as a valid approach for group decision-making (Saaty 1989; Dong et al. 2010; Krejčí and Stoklasa 2018; Guo et al. 2015), yielding results, i.e. the *weight vector* values shown in Table 5.

We have greyed out cells where one criterion is dominant (i.e., a significant preference) over the other. The last column ('Weight vector') corresponds to the eigenvector for the criteria x criteria table. It shows the overall importance of criteria, and the highest

Table 5. Proposed AHP model for the criteria judgements using group decision-making.

Criterion x Criterion Matrix

	A	B	C	D	E	F	G	H	I	**W**
A	**1**	3.9641	1	0.2872	1	6.5038	5.6191	0.2095	0.2106	*0.1232*
B	0.2523	**1**	1	4.6431	1	0.2373	1	6.9584	5.9137	*0.1341*
C	1	1	**1**	0.2427	5.1927	5.1093	1	0.2071	1	*0.1009*
D	3.4818	0.2154	4.1203	**1**	1	0.1840	1	6.8041	5.8122	*0.1424*
E	1	1	0.1926	1	**1**	1	1	0.2191	4.8287	*0.0688*
F	0.1538	4.2137	0.1957	5.4340	1	**1**	6.2185	5.8091	0.1832	*0.1541*
G	0.1780	1	1	1	1	0.1608	**1**	0.1664	1	*0.0043*
H	4.7729	0.1437	4.8287	0.1470	4.5635	0.1721	6.0103	**1**	1	*0.1428*
I	4.7484	0.1691	1	0.1721	0.2071	5.4589	1	1	**1**	*0.0894*

Legends:
A. Acquisition costs
B. Monthly costs
C. Reputation & references
D. Support & training
E. Deployment experience
F. Feature set
G. Easiness of use
H. Efficiency & reliability
I. Maintainability
W is the Weight Vector

value could be interpreted as the most important one, according to the respondents. For this case, the 'Feature set' was ranked at the top (according to the value of the weight vector, which is the highest one), followed by 'Efficiency' and then 'Support'. This indicates that, according to the chosen pairwise judgments, stakeholders consider 'Feature set' of an ERP as one of the most important attributes to consider. The table also shows the inherent tradeoffs present when deciding the acquisition of an ERP system and the dilemmas faced by decision makers. Managers want to adopt a system that will scale according to the company's needs, with minimum defects, errors and interface inconsistencies, at the same time providing updated and consistent information to users.

After addressing criteria-criteria pairwise judgements, it is necessary to assign weights per criterion to existing ERP systems, so a valid AHP model is devised. This model of criteria can be used for managers and stakeholders of companies interested in choosing or replacing ERP systems at any time of need for a decision-making process.

5.1 Comparing alternatives in the proposed AHP model

In order to use and evaluate the AHP model criteria proposed, we have chosen two domain experts (working on the healthcare segment) to direct interview about choosing an ERP to purchase. We have decided to do it in this qualitative way so we could have more control over the selected judgments, as it would be easier to explain the objectives of the study and the amount of work necessary to achieve our objectives. Both managers were trying to decide between two modern ERP systems with considerable brand name and adoption within the healthcare community.

For the sake of anonymity, we shall name the candidate ERPs as A and B. We have explained to these stakeholders that we would be adopting a *grading* system, composed by even numbers from 1 to 9 (reflecting Saaty's Judgement Scale). The questions formulated to the interviewees was structured with simplicity, i.e., *'Concerning criterion X, which ERP system is better or worse and by which factor, from 1 to 9?'*. We have opted to allow interviewees to comment on the answer, explaining the selected value. Table 6 shows the pairwise comparisons per criteria for the chosen alternatives for the first interviewee (#1).

Table 6 shows the tradeoffs for the two ERP systems, i.e., one is preferred over the other for different criteria. The AHP model was then inputted into the Decisor software tool (Czekster et al. 2019), computing the final ranking for the ERP selection. For the two ERP under study, the first one (A) is ranked with value 0.4394 whereas the second one (B) has yielded 0.5606, i.e., the suggested choice for the decision-making process is the ERP B. In retrospect, given the weights provided by the interviewee, it is possible to infer the criterion he considers the most important as well as the choice to be selected.

For the second interviewee (#2), we have used the same weights for the criteria since it is our model proposal. Table 7 shows the assigned weights by the second interviewee, between the same alternatives, as follows.

In this case, the interviewee recognizes the importance of easiness of use over other criteria; however, it was not clear its quantitative influence on the final results. It was interesting that both have chosen the same weights for Support & training, Deployment experience, and Efficiency & reliability. The value computed for ERP A equal to 0.3735 and

Table 6. Pairwise comparison per criterion between alternatives A and B for interviewee #1.

Acquisition costs	A	B
A	1	0.20
B	5	1
Monthly costs	A	B
A	1	0.33
B	3	1
Reput. & refer.	A	B
A	1	7
B	0.14	1
Sup. & train.	A	B
A	1	0.20
B	5	1
Depl. exper.	A	B
A	1	0.33
B	3	1
Feature set	A	B
A	1	7
B	0.14	1
Easiness of use	A	B
A	1	0.20
B	5	1
Effic. & reliab.	A	B
A	1	0.33
B	3	1
Maintainability	A	B
A	1	7
B	0.14	1

for ERP B equal to 0.6265, i.e., the ERP B should be selected as well, with more intensity (higher rank) in comparison with the previous interviewee. Those computations and rankings were produced by the software tool, which have used the numerical procedure set out by the AHP method (explanations on this are vastly discussed in the literature such as Saaty (1977), Saaty (1988), Ishizaka and Labib (2009), and Czekster et al. (2019), to cite a few). It takes into account the judgments assigned to the pairwise comparisons of criteria as well as per criterion, the pairwise comparisons with the alternatives, i.e., with respect to a given criterion, how the alternatives (in our case ERP A and ERP B) are better or worst (or the same) and with which intensity (the judgement scale).

6. Final considerations

The use of tools for supporting complex management operations is broadly employed. In this sense, the selection of a consistent and reliable ERP system must be made with care, considering relevant issues and characteristics. So, due to all possibilities and criteria that must be addressed, managers tend to resort to multicriteria decision methods to aid the selection of an ERP, which is the aim of the present work. One common MCDM used extensively throughout the years is AHP, mostly due to its simplicity and because it incorporates the influence of each alternative within the decision. Also, AHP allows quantitative decision-making for intangible quality measures.

Table 7. Pairwise comparison per criterion between alternatives A and B for interviewee #2.

Acquisition costs	A	B
A	1	1
B	1	1
Monthly costs	A	B
A	1	0.20
B	5	1
Reput. & refer.	A	B
A	1	0.33
B	3	1
Sup. & train.	A	B
A	1	0.20
B	5	1
Depl. exper.	A	B
A	1	0.33
B	3	1
Feature set	A	B
A	1	5
	0.20	1
Easiness of use	A	B
A	1	0.20
B	5	1
Effic. & reliab.	A	B
A	1	0.33
B	3	1
Maintainability	A	B
A	1	0.33
B	3	1

We have surveyed the literature and uncovered the most important criteria that must be considered when selecting an ERP, as stated in our objectives and research questions. We have proposed a meaningful approach to help managers and stakeholders to choose an ERP according to their needs. Among the several criteria present in recent researches, we have analysed and extracted nine crucial criteria for devising an AHP model. We have used questionnaires to derive the weights among those criteria and then interviews with selected domain experts for the alternatives scaling. With those quantitative values, we have used group decision-making for the criteria-criteria pairwise comparisons and then we have devised a criteria ranking in an AHP model proposal.

In order to demonstrate the usefulness of our criteria model, using the Decisor software, we have computed the ranking of two ERP software alternatives for healthcare managers. Our main contribution was to present and discuss the most important criteria one should consider when choosing ERP for SMEs with the presence of different trade-offs and characteristics.

6.1 Limitations of our approach

Our work has, however, some limitations. For example, we deeply rely on managers' judgements to provide a meaningful numerical counterpart for the AHP model. This is the major drawback of using any MCDM available as different scales have been proposed throughout the years to address those concerns. As observed, the judgement values are intrinsically sensitive in the model, as the final decision

could shift as the input varies (even by small amounts). AHP methodology presents ways to deal with those problems as it strongly relies on expert judgments to create useful models, which are prone to be revised at any time during the decision process.

It is worth mentioning that AHP is a simple method, where stakeholders with different backgrounds could explore the models very easily, helping decision-making processes. It suffices to define the list of criteria, the list of alternatives and the weights among those entities to yield a numerically sounded ranking among all possible alternatives.

Another limitation concerns the number of attributes one should consider when performing a decision analysis. In our case, we have selected nine criteria, which required a high number of pairwise comparisons (just for the criteria, 36 values were needed). Fewer attributes would certainly mean in fewer comparisons; however, this is a drawback of the AHP method itself, faced by many decision analysts.

6.2 Managerial implications and future works

One common problem facing medium-sized enterprises is which ERP one should acquire taking into consideration costs, software functionalities and training, easiness to use, among other characteristics. As a practical implication, our work has proposed a set of meaningful properties that stakeholders and managers should use to make the best decision as to the most reasonable ERP system one should purchase to meet company demands. Our approach could help decision-makers addressing the most important characteristics to consider when selecting an ERP as well as devising their own AHP models with their judgments, customizing the decision for each case. It is worth mentioning that the approach considered here was directed towards the use of multicriteria methods, specifically AHP, chosen due to simplicity. One could use other MCDM method of choice, e.g., ELECTRE, MAUT, VIKOR, or TOPSIS, to name a few, in order to evaluate other quality dimensions required by stakeholders.

As future works, we aim to apply the same questionnaire and interview to another segment, inspecting whether or not the criteria list could be employed, perhaps with minor adjustments or if another set of criteria must be addressed. We also aim to devise another AHP model for a general software selection, since we think that many criteria would be shared among those analyses. From the list of criteria, we are considering to remove some attributes and then re-apply the questionnaire to other stakeholders as well, decreasing the number of pairwise evaluations needed for the study. We could remove those criteria where the numerical value computed in the weight vector was too low. In our case, the criteria to be deleted would be 'Deployment experience' and 'Easiness to use' according to Table 5.

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ORCID

Ricardo M. Czekster http://orcid.org/0000-0002-6636-4398
Thais Webber http://orcid.org/0000-0002-8091-6021
César Augusto Missio Marcon http://orcid.org/0000-0002-7811-7896

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