Applications of MCDM Methods in the ERP System Selection Process in Enterprises

Summary

This research examines new directions in applications of Multiple Criteria Decision Making (MCDM) methods in the process of selecting appropriate ERP system by organizations. The research identifies and reviews the most relevant and influential publications, which formed the state of art in this research field. Tendencies of the use of MCDM methods are demonstrated by the means of comparative analysis. The first part of the paper introduces MCDM methods often used in the ERP system selection process. Second part of the paper provides literature analysis of various MCDM methods, their acceptance and frequency of application for selection of an ERP system.

Key words: Enterprise Resource Planning (ERP), Multiple Criteria Decision Making (MCDM), MCDM methods, ERP system selection criteria.

JEL codes: C88, M10, M16

Introduction

The essence of strategic choices is to make fundamental decisions determining organization’s future. Such decision making involves uncertainty and risk, because decision makers have to act within limited information, unpredictable conditions, and without being aware all of the consequences of their decisions. Uncertainty simply intensifies the variety of possible results, and the consequences of these results should be deliberated.

Enterprise Resource Planning (ERP) offers organization’s strategic thinkers support in dealing with uncertainty by helping to identify specific uncertainties, clarifying their possible results, evaluating possible consequences, and finally helping to evaluate strategic alternatives and make decisions reflecting a wide range of aspects and circumstances.

Enterprise Resource Planning is a modular information system, designated to provide a complete end-to-end, computerized solution for business processes management of mainly mid-size and large organizations. In the ERP system, interdependencies between different system modules, responsible for each business area and activity, increase the efficiency of each process conducted by the organization in particular and the operation as a whole. Due to its high permeability in the organization core processes, the ERP system implementation is
often the cause of organizational reengineering, simplification and integration of structures and business processes (Remenyi 2000).

As a derivation of these significant changes, the project size, complicated structure, high costs and tight schedule, the implementation project of a new ERP system is a potential threat on the organization financial stability (Ahituv, Neumann, Zviran 2002). Over the years, different factors have been recognized as relevant to the success or failure of an ERP implementation project. Some are more critical than others. One of the possible and chronologically early point of potential risk, is the ERP software selection process.

High costs and risks of such a misfit, make ERP software selection a critical factor with major impact on the organization’s financial future (Aloini, Dulmin, Mininno 2007). The failure percentages, on different phases of the implementation project, were the subject of research during last two decades. A significant partition such studies indicates high level of partial or complete failure, ranging from 21% up to 90% according to different criteria, i.e. budget, schedule, or return on investment (Langenwalter 2000; Ptak, Schragenheim 2000). One conclusion of these research studies is that misfit in the selection of a new ERP system may be strongly related to failure of the ERP implementation projects. As a consequence, a great number of research articles were published on that issue with a similar idea of suggesting the optimal method for selection. These methods vary, but many of them have in common the use of MCDM platform in their striving towards that goal.

Multiple Criteria Decision Making (MCDM, also knowns as MCDA – Multiple-criteria decision analysis, and MCE – Multi-criteria evaluation) methods are based on mathematical models with different level of complexity. Most of the methods are being a subject of constant improvement and changes, often by various researchers. One relatively new conception, which served as an inspiration for many methods renovations, was the Fuzzy Logic.

The purpose of this paper is to demonstrate the tendencies of MCDM methods application for an ERP system selection process in the past decades. The research identifies and reviews the most relevant and influential publications, which formed the state of art in this research field. Tendencies of the use of MCDM methods are demonstrated by the means of comparative analysis. In first part of the paper MCDM methods often used in the ERP system selection process will be introduced. In second part of the paper literature analysis of various MCDM methods, their acceptance and frequency of application for selection of an ERP system will be provided. The MCDM methods publications were compared and ranked by their amount and the number of their citations, which demonstrated their popularity and the tendencies in this researched filed.

Identification of MCDM methods being used in the ERP system selection process

Selection process of the most appropriate ERP system is one of the most influencing success factors on the ERP implementation project (Hasibuan, Dantes 2012). Consequently, it was described by wide variety of articles and research papers. Many of them concentrate
Table 1
Characteristics of the most popular MCDM methods being used for ERP system selection

<table>
<thead>
<tr>
<th>MCDM methods</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>AHP (Analytic hierarchy process)</td>
<td>The AHP is one of the earliest and the most common methodologies. It was published by Wind &amp; Saaty in 1980, and later modified into software and ERP system selection model by several researches, among them Teltumbde (2000), who proposed a framework based on the AHP method combined with Nominal Group Technique (NGT). The method is pairwise and includes three stages: decomposition (development of the hierarchy of criteria), comparative judgments (utilization of paired comparisons between the criteria by using nine-point scale) and synthesis of priorities (paired comparison process is repeated for each attribute). After all the comparisons accomplished, the results aggregated over the hierarchy. On one hand, the methodology allows multi criteria decision making, applicable when it’s difficult to formulate criteria, qualitative and quantitative evaluation is possible and so is group decision making. On the other hand, consistency during the evaluation process is assumed and there is a difficulty using the method when the number of criteria is high, new criterion is being added or existing one is being withdrawn (Forman, Gass 2001).</td>
</tr>
<tr>
<td>Fuzzy AHP</td>
<td>The method uses linguistic variables to indicate the comparative judgments made by decision makers of an organization using the stages of the AHP methodology (Chang 1996). Application of the fuzzy AHP to the ERP system selection process can reduce the uncertainty in the evaluation of criteria. On the other hand, it will not be evenly effective on all phases of the ERP system selection and implementation process (Cebeci 2009).</td>
</tr>
<tr>
<td>ANP (Analytic network process)</td>
<td>The ANP is an evolution of AHP. The main differences between these two models are that the ANP allows mutual relationship among all the hierarchy levels and the calculation in the ANP is made using the “Supermatrix” concept which allows interdependencies between attributes (Saaty 2004).</td>
</tr>
<tr>
<td>Fuzzy ANP</td>
<td>The fuzzy ANP was applied to the development of decision support system in attempt to reduce the uncertainty in decision-making problems (Mikhailov, Singh 2003). Ayağ and Özdemir (2007) used the fuzzy ANP as an ERP system selection methodology, defining a framework of criteria, dimensions and their attributes and later modifying them to fuzzy sets.</td>
</tr>
<tr>
<td>DEA (Data Envelopment Analysis)</td>
<td>The method uses DMUs (Decision Making Units) for describing incommensurate, in their efficiency input and output criteria. Due to the differences in the values of the inputs and outputs, it was suggested to use set of weights that can reflect the most correlative efficiency score (Charnes, Cooper, Rhodes 1978). Lall and Teyarachakul (2006), in their DEA model for selection of an ERP system, evaluated suitability using sets of system attributes criteria and vendor attributes criteria.</td>
</tr>
<tr>
<td>Fuzzy DEA</td>
<td>Applying fuzzy sets on efficiency measures DEA extension was suggested by Kao and Li (2000) and used by several researches as an ERP system selection method (Yang, Qin 2009).</td>
</tr>
<tr>
<td>QFD (Quality Function Deployment)</td>
<td>The method was presented by Akao (1997) and had been used, at first, by the Japanese automotive industry, later adapted to various fields. The QFD principal idea is the translation of customer requirements into a final product or service characteristics and prioritizing them with the use of House of quality - a matrix designed to demonstrate the relationship between customer and technical requirements, priorities and limitations. As an ERP system selection methodology QFD has the ability to identify the level of compatibility of the system attribute to the organization requirement.</td>
</tr>
<tr>
<td>MCDM methods</td>
<td>Characteristics</td>
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<td>-----------------------------</td>
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<tr>
<td>Fuzzy QFD</td>
<td>Numerous researchers applied fuzzy sets to QFD method translating inexact and bleary given inputs and organizational requirements into precise and coherent data. Sen and Baracli (2010) applied their fuzzy QFD method, grouping the criteria by functional and non-functional together with their importance weights and prioritizing them by suitability results to the organization requirements, as part of the enterprise software system selection. Integrative ERP system selection method was developed by Karsak and Özoğul (2009) including the QFD, fuzzy linear regression and goal programming.</td>
</tr>
<tr>
<td>Goal programming (GP)</td>
<td>The method that can take simultaneously multiple objectives in the consideration process and resulting with a set of solutions. The main difficulty of the standard model can be the determination of the goal value for each objective, due to the incomplete data that decision makers can acquire. Another weak point of the method, as of many others, is the lack of quantitative representation of the qualitative objects (Ramanathan, Ganesh 1995).</td>
</tr>
<tr>
<td>Fuzzy GP</td>
<td>Fuzzy extensions of the GP were suggested by several researches in order to overcome the difficulty of the standard model (Chen, Tsai 2001). As a strengthening for these weaknesses, in the ERP system selection process, the GP method often combined with one or more of the MCDM methods with their fuzzy extensions. In other words, GP can be utilised by other methods to perform simultaneous analysis and ranking (Karsak, Özoğul 2009), (Nikjoo, Khah, Moghimi 2011).</td>
</tr>
<tr>
<td>TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)</td>
<td>The method was introduced by Hwang and Yoon in 1981. Using weights to evaluate criteria and ranks the alternatives by their distance from the ideal and the worst alternative. It considered to be simple and intuitive method compared to others, while the use of a numerical valuation that might be considered as drawback of the classical TOPSIS method, can be overcame in its fuzzy extension by linguistic variables (Efe 2016; Junior et al. 2014).</td>
</tr>
<tr>
<td>ELECTRE (Elimination and Choice Expressing Reality)</td>
<td>This category includes a family of methods which are all evaluation of the original model (ELECTRE I, ELECTRE II, ELECTRE III, ELECTRE IV, ELECTRE IS, ELECTRE TRI). The method consists of two phase analysis, creating a set of alternatives that outrank other alternatives not included in the set and then ranking them by the relative importance, within the set, using criteria weights. This method often used as preliminary stage before using another, more sufficient, MCDM method in purpose to make the process more efficient (Figueira, Greco, Słowiński 2013).</td>
</tr>
<tr>
<td>PROMETHEE (Preference Ranking Organization Method for Enrichment of Evaluations)</td>
<td>The method allows pairwise comparisons of all selection alternatives and all criteria to establish interrelations between the alternatives that result in ranking them. This method, in resemblance to ELECTRE, is used in conjunction with other MCDM methods for software selection projects. For instance, ANP and PROMETHEE combination for SME’s ERP system selection (Kilic, Zaim, Delen 2015).</td>
</tr>
<tr>
<td>Other</td>
<td>VIKOR – Multi-criteria Optimization and Compromise Solution (Lin, Tzeng, Jen 2005); GRA – Grey relational analysis (Feng 2007); ITFZ – Intuitionistic Trapezoidal Fuzzy Information (Chen 2011); SMART - Simple Multi Attribute Rating Theory (Olson 2007).</td>
</tr>
</tbody>
</table>

Source: own elaboration.
on one of the popular decision making models and suggest a closed list of criteria. The correspondence of these suggested processes with each other is insufficient. Moreover, each one of them proposes different criteria or different views on the heftiness of similar factors.

Other group of suggested methods is the fruit of a hybrid approach, whose essence lies in the combination between the various additional models. There are also unique MCDM methods introduced by teams of researchers and usually not picked up for further development or study by others.

In the reviewed professional literature, there are several leading approaches and their fuzzy derivatives, prevalently used for decision-making process of selecting and implementing an ERP system. They are presented in Table 1.

The fuzzy approach, used in these MCDM methods, mainly concentrates on the uncertainty of the selection process by taking into consideration both quantitative and qualitative criteria (Junior, Osiro, Carpinetti 2014). The Fuzzy logic was presented by Zadeh (1965; 1994), who suggested it can be applicable to many other crisp methods by combining them together. In the last decades, fuzzy derivatives of the classic approaches have been frequently favoured over the original ones as a selection method and researched by a variety of studies. Another popular approach is the combination between fuzzy methods and the non-fuzzy ones or between the fuzzy methods among themselves (Enea, Piazza 2004; Mohanty et al. 2005).

In general, combination of different MCDM methods can be used to overcome the cons of each one of the methods. Thus, one of the methods in the tandem takes responsibility for one part of the decision making process, usually modifying and converting qualitative or linguistic data into quantitative data. The other one takes the duty of ranking and prioritizing the selection criteria, that is the quantitative data processing and analysis.

Comparative analysis of MCDM methods applications in the ERP system selection process

Research Methodology

Completing literature review allowed the identification of key terms describing the MCDM methods of ERP system selection process. The list of terms included “MCDM”, “MCDA” and “planning system”. In addition these terms were combined and used in conjunction with “method”, “approach”, “evaluation” “selection”, “ERP system” and “Enterprise Resource Planning System” terms, followed by specific names of the MCDM methods covered in the literature review. The range of years was defined to be between the year 2000 and 2016.

The search process was carried out using the Harzing Publish or Perish software which used the scholar.google.com as its database. The search was performed on 16 August 2016 and conducted by the authors of this paper. The results were checked and duplicate pub-
lications by same authors, such as conference reports on the published research, were removed. The final list of publications was reviewed and sorted by the MCDM method issued. Numbers of publications were found after the analysis of the references of the publications that met search criteria in the previous phase.

Data that was retrieved included the year of the publication and the amount of citations on the search date. During the next phase the findings had been processed and the abstract of each one of them were analysed.

The findings then were sorted and grouped by two criteria, A and B.

Grouping by criteria A reflected the specific MCDM method, used in the research that is being sorted. Grouping by criteria B classified the reviewed publications by their affiliation to the following groups: “Classic” that described application of commonly used MCDM methods, “Fuzzy” that used combination of classic MCDM method with Fuzzy sets approach, “Integrated” for integration or combination of more than one MCDM method in the study and “Other”, containing the MCDM methods that were developed and used only within the reviewed research or MCDM method not included in any of the other groups.

**Results**

After performing the search process as described, 189 publications were picked and reviewed.

The findings listed in Table 2 indicate that the tendency of applying MCDM method to the selection of an ERP system had increased starting 2005 and came to its pick in 2012. The main volume of publication focuses on the AHP, Fuzzy AHP and AHP integrated with other MCDM method. Another phenomenon is the large amount of unique MCDM applications suggested by variety of researchers as a possible solution.

The decreasing amount of studies on the last years (Figure 1) can imply that the suggested MCDM approaches gave an adequate solution for the issue although no evidence of widely accepted approach was noted.

From analysing the number of citations per publication for each one of the MCDM methods, grouped by criteria A, during the discussed period, it can be noted that AHP, fuzzy AHP and integrated AHP have cumulative 41% of all cited MCDM methods in the reviewed literature (Figure 2). This high percentage can be explained by the early appearance and high popularity of the general AHP approach what gave enough time and material for researchers to develop application for the ERP system selection process. Another reason can be the AHP approaches suitability for dealing with the selection process of ERP system, probably due to its capability to deal with qualitative and quantitative data.

Analysis result of the cited publication Grouped by criteria B (Figure 3) shows that over 52% belong to fuzzy and integrated MCDM approaches. Taken into account that fuzzy sets applied to classical MCDM methods are already a type of integrated approaches and publications grouped under “Other” often also suggest integrated approaches, it can be concluded
that the concept of integration between different MCDM methods gained considerable popularity. This need to combine can be justified by the limitations each MCDM method has in various aspects and phases of the method and their disability to deal with all the complexity of selection process within one specific model.

Table 2

MCDM publications by criteria A and B grouping (publications count per year)

<table>
<thead>
<tr>
<th>MCDM type (criteria A and B grouping)</th>
<th>Year of Publication</th>
</tr>
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<tbody>
<tr>
<td>AHP</td>
<td>-</td>
</tr>
<tr>
<td>ANP</td>
<td>-</td>
</tr>
<tr>
<td>DEA</td>
<td>-</td>
</tr>
<tr>
<td>ELECTRE</td>
<td>-</td>
</tr>
<tr>
<td>QFD</td>
<td>-</td>
</tr>
<tr>
<td>TOPSIS</td>
<td>-</td>
</tr>
<tr>
<td>Classic total</td>
<td>0</td>
</tr>
<tr>
<td>Fuzzy AHP</td>
<td>-</td>
</tr>
<tr>
<td>Fuzzy ANP</td>
<td>-</td>
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<tr>
<td>Fuzzy DEA</td>
<td>-</td>
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<tr>
<td>Fuzzy GP</td>
<td>-</td>
</tr>
<tr>
<td>Fuzzy QFD</td>
<td>-</td>
</tr>
<tr>
<td>Fuzzy TOPSIS</td>
<td>-</td>
</tr>
<tr>
<td>Fuzzy total</td>
<td>0</td>
</tr>
<tr>
<td>INT AHP</td>
<td>-</td>
</tr>
<tr>
<td>INT ANP</td>
<td>-</td>
</tr>
<tr>
<td>INT GP</td>
<td>-</td>
</tr>
<tr>
<td>INT PROMETHEE</td>
<td>-</td>
</tr>
<tr>
<td>INT QFD</td>
<td>-</td>
</tr>
<tr>
<td>INT TOPSIS</td>
<td>-</td>
</tr>
<tr>
<td>Integrated total</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: as in Table 1.
Figure 1
The dynamics of MCDM publications

Source: own elaboration.

Figure 2
Publications cited by between the years 2000-2016 (grouped by criteria A)

Source: as in Figure 1.
One of the main factors, which leads to the integration constraint, noted in the literature review, is the need of a qualitative data processing and of converting qualitative information to quantitative data. Such example can be observed in the case of the GP method which has no ability to handle qualitative data, if not converted to quantitative form and using other MCDM method to perform this operation (Ramanathan, Ganesh 1995). The results of the analysis can ratify this claim. Thus, the GP method by itself has no publications, as for an ERP system selection process research and case study. However it has 10% from all cited publications as a participant of an integrated approach in this field studies.

Conclusions

MCDM methods have the ability to take into consideration and process the multiple criteria and their weights and therefore been widely used as a solution instrument for the ERP system selection problem. The analysed literature reveals patterns of research and application of different types of MCDM methods over the years. These patterns can be used as a basis for further research and study of the different approaches for selecting the most appropriate ERP system for an organization.

Although trends in the research of this field can be analysed differently, the analysis presented in this paper shows the need of combined, integrated method that offers not only a strong, quantitative model, but can measure and reflect a qualitative input of information
and data. For example, quantitative, mathematical MCDM method such as GP method are not adequate enough for handling spectrum of qualitative information and data independently, what urges the need of combination with other selection methods.

Another important conclusion that was drowned during the analysis of the different MCDM methods application in the ERP system selection field is the popularity of the AHP approach along with its fuzzy and integrated applications as well as large amount of unique MCDM methods suggested by various researches and covered by many case studies. The analysis revealed the decreasing number of studies issued MCDM methods application to the ERP system selection process over the last couple of years. Nevertheless, no unified or agreed method was identified or accepted by the researchers or industry companies.

The research reviled variety of methods, opinions spread and absence of accepted or agreed method. In order to reduce this gap, further research should be performed in the direction of developing a complete, comprehensive method that will be widely accepted and used for resolving the ERP system selection problem.

Bibliography


Wykorzystanie metod wielokryterialnej analizy decyzyjnej w procesie wyboru systemu ERP w przedsiębiorstwach

Streszczenie

Przedmiotem opracowania jest wykorzystanie metod wielokryterialnej analizy decyzyjnej w procesie wyboru odpowiedniego systemu klasy ERP w organizacjach. W ramach przeprowadzonego badania zidentyfikowano oraz poddano analizie najbardziej uznanie i opiniotwórcze publikacje, tworzące bazę teoretyczną omawianej problematyki. Celem opracowania jest identyfikacja tendencji obserwowanych w zakresie wykorzystania omawianych metod. Pierwsza część opracowania zawiera prezentację najpopularniejszych metod wielokryterialnej analizy decyzyjnej wykorzystywanych w procesie wyboru systemów klasy ERP w organizacjach. W drugiej części opracowania przedstawiono wyniki badań literaturowych dotyczących popularności oraz znaczenia omawianych metod, mierzonej liczebnością publikacji oraz liczbą cytowań w literaturze przedmiotu.

Słowa kluczowe: system ERP, wielokryterialna analiza decyzyjna, metody wielokryterialnej analizy decyzyjnej, kryteria wyboru systemu ERP.

Kody JEL: C88, M10, M16

Использование методов многокритериального анализа принятия решений в процессе выбора системы ERP (планирования ресурсов предприятия) на предприятиях

Резюме

Предмет разработки – использование методов многокритериального анализа принятия решений в процессе выбора соответствующей системы класса ERP в организациях. В рамках проведенного изучения выявили и провели анализ наиболее признанных и формирующих общественное мнение публикаций, создающих теоретическую основу рассматриваемой проблематики. Цель разработки – выявить тенденции, наблюдаемые в области использования обсуждаемых методов. Первая часть разработки содержит презентацию самых популярных методов многокритериального анализа принятия решений, используемых в процессе выбора систем класса ERP в организациях. Во второй части работы представлены результаты изучения литературы в отношении популярности и значения рассматриваемых методов, измеряемых числом публикаций и цитирований в литературе предмета.
APPLICATIONS OF MCDM METHODS IN THE ERP SYSTEM SELECTION PROCESS...

Ключевые слова: система ERP, многокритериальный анализ принятия решений, методы многокритериального анализа принятия решений, критерии выбора системы ERP.

Коды JEL: C88, M10, M16

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Afiliacje:
dr Maciej Brzozowski
Uniwersytet Ekonomiczny w Poznaniu,
Wydział Zarządzania
Katedra Zarządzania Strategicznego
Al. Niepodległości 10
61-875 Poznań
e-mail: m.brzozowski@ue.poznan.pl

Ilya Birfer
Jerusalem College of Technology - Lev Academic Center
Faculty of Management
Department of Accounting & Information Systems
21 Havaad Haleumi St., P.O Box 16031
Jerusalem 9116001, Israel
e-mail: Ilya.erp@gmail.com