Applied Soft Computing 32 (2015) 347–368

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

A novel credibility-based group decision making method for Enterprise Architecture scenario analysis using Data Envelopment Analysis

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ARTICLE INFO

Article history:
Received 10 April 2013
Received in revised form 20 February 2015
Accepted 30 March 2015
Available online 7 April 2015

Keywords:
Data Envelopment Analysis
Fuzzy credibility constrained programming
Enterprise Architecture
COBIT
Group decision making
p-Robustness

ABSTRACT

Analysis and selection of Enterprise Architecture (EA) scenarios is a difficult and complex decision making process directly effecting the long-term business strategies realization. This complexity is associated with contradictory objectives and significant uncertainties involved in analysis process. Although a large body of intuitive and analytical models for EA analysis has evolved over the last few years, none of them leads to an efficient and optimized ranking in fuzzy environments. Moreover, it is necessary to simultaneously employ some complementary methods to reflect the ambiguity and vagueness as the main sources of uncertainty. This paper incorporates the concept of Data Envelopment Analysis (DEA) model into EA scenario analysis through a group analysis under uncertain conditions. To resolve the vagueness and ambiguity of the EA analysis, fuzzy credibility constrained programming and p-robustness technique are applied, respectively. Not only is the proposed DEA model linear, robust, and flexible in aggregating experts' opinion in a group decision making process, but it also is successful in discrimination power improvement – a major shortcoming associated with classic DEA model. The proposed model provides useful solutions to support decision making process for large-scale Information Technology (IT) development planning.

1. Introduction

Nowadays, EA has become an established approach for holistic IT management to facilitate rational decision making in diverse organizations [1]. Increased business agility and improved organizational performance are some advantages of EA. To improve the highly complex and interconnected IT-related issues of an organization, a suitable EA scenario should be designed, which usually needs extreme financial investment and bears severe risks [2]. Given the critical aspect of choosing an applicable EA scenario, the Clinger–Cohen Act, a 1996 United States federal law, was designed to enforce the adoption of an EA approach by agencies. In this regard, organizations are confronted with various choices for IT development in form of EA scenarios. Achieving the most appropriate EA scenario is however a great challenge that to a large extent can be addressed by introducing an efficient and optimal analysis model.

Due to the essential and fundamental impact of EA scenarios in today's organizations, the selection of the right EA scenario considering the business strategies of the enterprise is regarded as one of the most important and complex decision making problems [3]. Architects and stakeholders need a precise method to compare EA scenarios and have a sensitive analysis to know the impact of their decisions [4]. With respect to the complexity and size of EA scenarios, a sophisticated group decision making method is required to be used under fuzzy environment. Furthermore, experts' opinions often conflict in group decision making. This can make the analysis process more incomprehensible. Therefore, a comprehensive and optimal approach is required to facilitate the selection process of the right EA scenario that fits the capabilities and strategies of an enterprise via a systematic approach before any implementation takes place. In this research, we propose a robust group DEA model to overcome the complexities of this decision making process in conditions of uncertainty. The additional contributions of our research to the extant literature are as following main issues.

First, for the decision making process in EA scenario analysis, we have employed DEA paradigm – a well-known decision

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http://dx.doi.org/10.1016/j.asoc.2015.03.052
1568-4946/

making approach – to evaluate a set of decision making units (DMUs) based on the multi input–output performance measures [5]. The justification behind our choices are explained as follows:

1. Comprehensive value measurements are not required.
2. Production or cost functions are not necessary, while inputs and outputs can be obtained effectively using different units of measurement [6].
3. There is no need for priori weights on inputs and outputs [7].
4. The performance of each DMU is determined according to an ideal DMU rather than the average efficiency of DMUs [7].
5. Although most multi criteria decision making (MCDM) methods require several parameters, it is a non-parametric method not needing an exact determination and analysis of the parameters at the beginning or at the end of decision making procedure for sensitive analysis [7–9].
6. It uses linear programming to determine the efficiency of DMUs [10].

To the best of our knowledge, we are the first to leverage DEA model as an efficient optimal EA scenario selection tool.

Second, since the EA scenario selection is a complex and complicated decision making process, it needs the overall wisdom of an expert team. We use a group DEA model to compensate for the inherent lack of knowledge of individuals.

Third, in a group DEA used in our approach, there are two main sources of uncertainty. While the vagueness is associated with lack of precision in experts' opinions, ambiguity is due to multiple interpretations of experts. Although possibility theory has been applied in original DEA model [11,12], the necessity theory is another aspect of uncertainty which should be considered in overcoming the vagueness of fuzzy decision making. Therefore, fuzzy credibility constrained programming is applied in this paper to deal with the vagueness embedded in experts' judgment by considering both possibility and necessity theory in DEA model. Self-duality, an essential property for practical measures, is not supported in possibility measures and necessity measures [11,13]. The applied credibility measure in DEA model warrants the self-dual property in both theory and practice [14].

Fourth, inaccurate judgments of different experts and aggregating experts' opinions in a group decision making process causes ambiguity. To ensure that the results of EA scenario analysis are guaranteed to be good, reliable, and robust for all possible realizations of ambiguous parameters, p-robustness optimization is incorporated into group decision making process. In fact, p-robustness optimization is applied to DEA for modeling the ambiguity associated with the group decision making. Moreover, discriminating power is a principal deficiency in DEA arising when the number of DMUs is not large enough compared to the total number of inputs and outputs. Hence, p-robustness applied in DEA solves the problem of discriminating power as well.

Fifth, regardless of the method employed, different criteria were taken into consideration for EA analysis. Some of the most dominant criteria are dedicated to software quality assessment [15] and the other main parts of the applied criteria are related to information system analysis [16]. However, these criteria do not reflect a comprehensive criteria set for EA scenario analysis. An EA scenario should encompass the main components of an enterprise including IT systems and the way these components interact with and support each other to achieve the business objectives [2]. Owing to this fact, a famous IT governance framework is used as an effective criteria model for EA scenario analysis to ensure the alignment of both business and IT strategies in the selected EA scenario.

Finally, the application case is accomplished for the most famous IT research center of Iran to select the best proposed EA scenarios. The efficiency of the proposed model in real-life contexts is compared with some popular and appropriate benchmark DEA models customized to be used in group analysis. In this regard, the fuzzy nature of the case study is represented as much as possible to raise the satisfaction in experts involved in the decision making process.

The remaining structure of the paper is sketched as follows: the literature review of EA analysis is highlighted in the next section. Then, the proposed model and the required preliminary concepts are presented in Section 3. Afterwards, the application case-study of the proposed model to the most famous ICT research center of Iran is introduced. This section is followed by several numerical experiments to validate the performance of the proposed model. Finally, the last section concludes and explains possible open areas for the future research.

2. Literature review

Nowadays, EA analysis is an essential tool in achieving organizational efficiency and effectiveness [17]. Although there are many EA analysis methods in the literature of the context, there is a lack of an adequate group decision making model for analyzing the proposed EA scenarios in conditions of uncertainty [18]. The extant literature on the EA analysis include different models: models used for analyzing a single EA, models applied for analyzing some proposed EA scenarios in order to select the most appropriate one for IT development.

In a single EA analysis, system and software architectures are the most important sub-layers of EA considered for the analysis [19,20]. Lagerström et al. [18] presented an analytical model based on a meta-model for enterprise systems modifiability analysis in uncertain environment. This model evaluates the cost of changes in several enterprise systems for each software project with probabilistic relational models. Johnson et al. [21] analyzed the EA from information systems viewpoints using extended influence diagrams. Bojanc et al. [22] analyzed security risks and digital assets of an enterprise for the technology investment purpose using some economic metrics. Huang et al. [23] proposed a network-based approach to reduce the risk and increase the business value. Several frameworks exist for evaluating the EA maturity for choosing and implementing the processes and artifacts of IT [24]. Jahani et al. [25] presented a general maturity model emphasizing resource availability. Balanced score card technique was also used by Kang et al. [26] to analyze the requirement for achieving the enterprise strategies. Some of these frameworks are used for EA analysis in time reference dimension [27]. The probabilistic relation model was considered for EA analysis to estimate service response time [28]. Moreover, Iacob and Jonkers [29] presented a quantitative analysis model through a top-down distribution of workload parameters of enterprise and a bottom-up distribution of performance and cost measures.

Since the scope of EA affects both the internal resources and the external information flow of an organization, it is recommended to consider several EA alternatives and choose the best one according to the considered criteria before any implementation takes place [30]. For EA scenarios analysis, MCDM methods are employed. Analytical Hierarchical Process (AHP) and fuzzy AHP are the most studied MCDM techniques in this category [3,31]. Zhu et al. [32] used AHP for software architecture analysis, and Reddy et al. [33] combined AHP and goal programming for this purpose. Chou et al. [24] proposed a two-stage fuzzy MCDM model for IT investment. Razavi et al. [3] used AHP for EA analysis based on quality attributes. Khajooei and Nasrabadi [34] analyzed the EA scenarios in one of the biggest Iranian food companies using fuzzy AHP method. Zandi and Tavana [17] proposed a fuzzy group