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A method for the evaluation of risk in IT projects

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ABSTRACT

Information technology projects are particularly prone to failure due to their specific characteristics, making risk management become one of the critical elements in IT projects management. That is why several authors have developed risk evaluation methods, some of them based on fuzzy logic. This article proposes a new risk assessment method based in a combination of fuzzy analytic hierarchy process (FAHP) and fuzzy inference system (FIS). FIS is used for the integration of the groups of risk factors. These risk factors are the evaluation criteria of a modified FAHP which minimizes the disadvantages of the classic implementation of FAHP in order to obtain a more intuitive and easily adjustable model for multicriteria decision analysis with a lower computational need. The proposed model takes into consideration the different levels of uncertainty, the interrelationship among groups of risk factors, and the possibility of adding or suppressing options without losing the consistency with previous evaluations. The new method is especially suitable for the evaluation of development projects in the area of IT in which multiple interrelated risk factors can be particularly uncertain and imprecise. To implement the evaluation method, a hierarchy of risk factors was implemented. A numerical example is presented with data from three actual cases of IT projects, showing the applicability of the new method, the suitability of the selected taxonomy, and the significance of a few risk factors. Several future lines of work are proposed.

1. Introduction

A project is a temporary organization to obtain a unique product (PMI, 2013) and risk management constitutes an integral part of the general project management (Cooper, Grey, Raymond, & Walker, 2005; Mignerat & Rivard, 2012). The definition of risk usually refers to uncertain events that may affect the project success, due to effects (Hillson, 2002) in cost, time, or in the quality of the project deliverables. The evaluation of the level of risk in a project involves two aspects: the probability of materialization of the risk events and the expected magnitude of their effects (Haimes, 2004). Both aspects are affected by uncertainty, imprecision and subjectivity.

Uncertainty, imprecision and subjectivity, are aggravated in Information Technology projects due to their specific characteristics (Fu, Li, & Chen, 2012; Gu, Hoffman, Cao, & Schniederjans, 2014; Savolainen, Ahonen, & Richardson, 2012) with a considerable amount of interrelated risk factors (Coombs, 2015; Lehtinen, Mäntylä, Vanhanen, Itkonen, & Lassenius, 2014) leading to a higher failure rate (Altahtooh & Emsley, 2014; Flyvbjerg & Budzier, 2011; Kawamura & Takano, 2014; Perkusich, Soares, Almeida, & Perkusich, 2015; Whitney & Daniels, 2013). To try to deal with these problems, several methods have been proposed for the assessment of risk in IT projects, some of them based on fuzzy logic (Elzamly & Hussin, 2014; Goyal, Satapathy, & Rath, 2015; Samantra, Datta, & Mahapatra, 2014; Taylan, 2014). Fuzzy logic permits the use of linguistic variables and is especially suitable to deal with uncertainty and ambiguity. Moreover, methods for the assessment of risk in IT projects that are based on AHP (Wu & Teng, 2010) can implement pairwise comparison for a more intuitive evaluation, and a hierarchy to deal with a certain amount of risk factors; while methods based on FIS (Pourdarab, Nosratabadi, & Nadali, 2011) incorporate expert knowledge and take into account the interrelationship among risk factors.

Fuzzy logic (Zadeh, 1965) substitutes the classic crisp two-valued logic (true and false) with continuous graded membership functions that go from absolute true to absolute false. Fuzzy logic is useful for processing subjective evaluations and permits the implementation of mathematical models for the analysis of uncertain and imprecise situations (Wong & Lai, 2011). That is why it is suitable to deal with risk evaluation (Huang, Zhao, & Tang, 2009; Lin, Chen, & Peng, 2012; Liu et al., 2012; Wu, Zhang, Wu, & Olson, 2010).

Analytic Hierarchy Process (AHP) (Saaty, 1980) is a methodology for multicriteria decision-making (MCDM) (Saaty, 2008) that builds

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a hierarchy of criteria to evaluate options. AHP calculates the criteria weights and performs the evaluation of options through pair-wise comparisons. The pair-wise comparison is more intuitive and usually more coherent than the isolated assignation of values. The hierarchical scheme brings a more organized vision of the problem, providing the structure for analyzing and grouping decision criteria. AHP has been widely used for evaluation and decision making in different areas (Subramanian & Ramanathan, 2012) including risk assessment (Dey, 2010).

Fuzzy AHP (FAHP) (Van Laarhoven & Pedrycz, 1983) is a technique based on fuzzy logic and AHP which inherits the advantages of both (Ishizaka, 2014) and is often implemented with fuzzy triangular numbers (FTN) (Chang, 1996) as membership functions. FAHP can be used for the evaluation and ranking of alternatives (Kahraman, Cebeci, & Ruan, 2004; Mikhailov & Tsvetinov, 2004; Rodríguez, Ortega, & Concepción, 2013; Sinuany-Stern, 1988). FAHP has the advantage of permitting the use of linguistic values which are suitable to deal with the imprecision and subjectivity of risk.

Fuzzy inference systems (FIS) (Mamdani, 1974) (also known as fuzzy rule based systems or FRBS) use inference rules to establish relationships between fuzzy variables to produce numeric output values from linguistic values associated to membership functions. FIS can be used for evaluation and classification purposes (Hudec & Vujošević, 2012).

FIS has the advantage of the implementation of expert judgment through inference rules and the consideration of the interdependence among variables; FIS adjustment is simple and the inference mechanisms can be easily represented by surface graphs.

Nevertheless, AHP (crisp AHP or FAHP) and FIS have some drawbacks.

AHP has been criticized by many authors (Bana e Costa & Vansnick, 2008; Belton & Gear, 1983; Wang & Chin, 2009).

The number of options to be evaluated with AHP will be limited by the human capability to perform simultaneous pair-wise comparisons (Junior, Osiro, & Carpinetti, 2013), values assigned to pair comparisons can be affected by subjectivity (Saen, 2010) and need to be verified for consistency.

AHP is a comparative method in which the entry of a new option will probably change the values previously assigned to others. AHP lack learning capabilities to introduce expert judgment (Castro-Schez, Miguel, Herrera, & Albusac, 2013).

Interdependence between factors is not considered in AHP. Analytical network process (ANP) (Saaty, 1996) is a more general form of AHP that takes into consideration the interaction between factors but ANP implementation is more complex (Abdolshah & Moradi, 2013; Hodgett, 2013; Mazurek & Kiszová, 2012) and it shares other disadvantages present in AHP (Salo & Hämäläinen, 1997).

Wang, Luo, and Hua (2008) demonstrate that fuzzy AHP may drive to a wrong decision due to the calculation of weights that do not represent the relative importance of the evaluation criteria (Rodríguez, 2015). Fuzzy AHP assigns zero weight to some evaluation criteria causing the waste of information.

Ishizaka and Nguyen (2013) describe the lack of indications of how membership functions can be constructed, identifying 27 different representations of fuzzy membership functions, none of them justified.

Rank reversal is the most debated problem of AHP (Ishizaka & Labib, 2009). It arises not only in AHP, but in other decision analysis methodologies (Wang & Luo, 2009), and consists in an inversion in the position in a ranking when an option is suppressed or a new one is added.

Some modifications have been proposed to avoid these problems (Wang & Chin, 2009, 2011; Wang & Elhag, 2006). Some authors minimize the importance of rank reversal (Triantaphyllou & Lin, 1996; Zanakis, Solomon, Wishart, & Dublish, 1998) and others suggest that it is an inherent aspect of decision making and consider that, despite this and other problems, AHP and similar techniques should be considered useful tools for decision making (Ishizaka & Labib, 2011; Kujawski, 2003; Tavana & Hatami-Marbini, 2011). After a very comprehensive and detailed review of the limitations of AHP, Ishizaka and Labib (2009) conclude that, despite still suffering from some theoretical disputes, AHP has reached a compromise solution between right modeling and usability that is the reason of its widespread use.

FIS may suffer of redundancy and inconsistency (Fantana, Weisbrod, Brown, & Forschungszentrum, 1996; Štěpničkova, Štěpnička, & Dvořak, 2013) and has the disadvantage of being able to implement only a few evaluation criteria; otherwise, the number of inference rules may become unmanageable.

The contribution of the research described in this paper consists in the development of a new method for the quantitative evaluation of the overall level of risk in projects using risk factors as evaluation criteria. The proposed method is based on a combination of FAHP and FIS, benefiting from their advantages and minimizing their disadvantages. It is based on a new approach to FAHP with classic pair-wise comparison for weight calculation and independent evaluation (Tüysüz & Kahraman, 2006) of risk factors. The highest level of the hierarchy is implemented through a Mamdani fuzzy inference system (FIS) (Mamdani, 1974). Other groups in the hierarchy may also be integrated by FIS.

The approach to FAHP proposed in this paper avoids the undesired assignation of null weights; justifies the construction of the membership function by implementing a measure of the evaluation uncertainty; suggest procedures for rank reversal verification; and presents a graphical method for AHP consistency assurance that simplifies the process. The autonomous evaluation (Tüysüz & Kahraman, 2006) permits the independent evaluation of projects in which the results obtained are not affected by the inclusion or exclusion of new options, permitting future comparisons and eliminating one cause of rank reversal. The use of FIS (Mamdani, 1974) facilitates the integration of expert knowledge and implements a more intuitive and adjustable model that takes into consideration the interrelationship among factors. The use of surface graphs helps to detect possible inconsistencies in the FIS implementation. Furthermore, being used only for the integration of a few evaluation criteria, FIS implementation becomes simple and the probability of redundancy is low.

2. Related work

Several authors propose FIS for the implementation of decision making methods (Danisman, Bilasco, & Martinet, 2015; Hasan, Shohag, Azeem, & Paul, 2015; Kumar, Deep, Suthar, Dastidar, & Sreekrishnan, 2015; Nakashima-Paniagua, Doucette, & Moussa, 2014) some of them for the evaluation of risk (Camastra et al., 2015; Chandima Ratnayake, 2015; Paul, 2015). Other authors propose decision making methods based on FAHP (Budak & Ustundag, 2015; Dong, Li, & Zhang, 2015; Jaiswal, Ghosh, Lohani, & Thomas, 2015), including methods for risk evaluation (Mangla, Kumar, & Barua, 2015; Nezarat, Sereshki, & Ataei, 2015; Ni et al., 2015).

Some authors propose ways of combining AHP and FIS for the implementation of decision making methods in general, or for the implementation of risk evaluation methods in particular.

There are several methods in which some aspects are evaluated with crisp or fuzzy AHP and others, in parallel, with FIS; both methodologies are applied separately (Bon & Utami, 2014; Kinlic, 2010; Makui & Nikkhah, 2011), so they cannot be adequately considered as combinations.

Some authors use FIS as an evaluation method, and crisp AHP for the selection of evaluation criteria and the assignation of weights to them (Carreño, Cardona, & Barbat, 2012; Donevska, Gorsevski, Jovanovski, & Peševski, 2012; Nilashi et al., 2015). They incorporate the