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Innovative Applications of O.R.

Multistage decision-making fuzzy methodology for optimal investments based on experts' evaluations

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ABSTRACT

A new methodology of making a decision on an optimal investment in several projects is proposed. The methodology is based on experts' evaluations and consists of three stages. In the first stage, Kaufmann's expertons method is used to reduce a possibly large number of applicants for credit. Using the combined expert data, the credit risk level is determined for each project. Only the projects with low risks are selected.

In the second stage, the model of refined decisions is constructed using the new modification of the previously proposed possibilistic discrimination analysis method (Sirbiladze, Khutsisvili, & Dvalishvili, 2010). This stage is based on expert knowledge and experience. The projects selected in the first stage are compared in order to identify high-quality ones among them. The possibility levels of experts' preferences are calculated and the projects are ranked.

Finally, the third stage deals with the bicriteria discrete optimization problem whose solution makes it possible to arrange the most advantageous investment in several projects simultaneously. The decision on funding the selected projects is made and an optimal distribution of the allocated investment amount among them is provided.

The efficiency of the proposed methodology is illustrated by an example.

1. Introduction

The decision support methodology and optimization play a significant role in improving nearly every aspect of the human society's life. Intensive studies carried out in recent years have led to a noticeable progress in decision-making science and optimization from both theoretical and practical standpoints. Optimization and decision-making problems for complex systems are traditionally solved using either the deterministic numerical or the probabilistic approach. The first of these approaches provides an approximate solution that totally ignores uncertainty and the other assumes that any uncertainty can be represented as a probability distribution. Both approaches only partly take into account the factor of uncertainty which actually exists in the form of known possibility distributions. Bellman and Zadeh (1970), Dubois and Prade (1988), Klir and Wierman (1999), Liu (2002), Yager (2002, 2007), Sirbiladze (2009a, 2009b, 2010a, 2010b), Sirbiladze, Khutsisvili, and Dvalishvili (2010), Sirbiladze et al. (2011), and Durbach and Stewart (2011, 2012) and other authors clearly support the use of the fuzzy set theory, fuzzy aggregation methods and soft computing techniques to further expand the human capability to make optimal decisions that take into account non-probabilistic uncertainty.

In the environment of market economy and competition, investments are exposed to the risk of loss, especially in the sphere of crediting. Hence the issue of increasing the effectiveness of credit policies and lowering credit risks becomes very topical (Aliev, Fazlollahi, & Aliev, 2004; Ruan, Kacprzyk, & Fedrizzi, 2001; Uyemura & Van Deventer, 1993; Wu & Olson, 2010 and others).

To examine the nature of risks related to financial decisions, various special methods are used. Along with the traditional statistical techniques, new credit scoring models are developed to support credit decisions. The ultimate goal of these models is to decrease imprecision and uncertainty in credit decisions so that creditworthy applicants could be granted credit, thereby increasing the profit of a bank, and non-creditworthy applicants could be denied credit, thus decreasing bank losses.

The analysis of investment projects involves experts' evaluations that may become dominant in the decision making process. Experts' qualitative (verbal) evaluations can be correctly processed by applying possibility analysis and the fuzzy-set approach (Aliev et al., 2004; Dubois & Prade, 1988; Hájek, 2012; Klir & Wierman, 1999; Ruan et al., 2001; Wu, Zhang, Wu, & Olson, 2010 and others). In particular, when analyzing the risks of bank investments, the set of possible risks can be described by means of the following fuzzy

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terms of the linguistic variable "risk" (Sirbiladze, Sikharulidze, & Korakhashvili, 2003): *an ultimate risk of unsuccessful investment*, *a high risk of unsuccessful investment*, *an average risk of unsuccessful investment*, *a low risk of unsuccessful investment*, *an insignificant risk of unsuccessful investment*. Then models based on the fuzzy-set methodology establish a functional correlation between the experts' verbal information (in the form of linguistic variables) and the membership functions of the fuzzy terms of linguistic variables, which indicate an extent of membership of the measured parameters (in our case, credit worthiness) in fuzzy descriptions.

Thus the investment decision-making process is influenced by various uncertainty factors as well as by the need to formalize and process fuzzy, insufficient and, mostly, expert data. The ignoring of these factors results in inadequate decisions.

Due to a high reliability of decisions made by expert systems developed on this basis, the fuzzy set theory has an indisputable advantage over probabilistic approaches, especially, when applied to problems of credit risk evaluation. Fuzzy statistics, possibility approaches and methods of fuzzy optimization are widely used when solving problems by modeling optimal decisions and especially when constructing decision support systems (Bellman and Zadeh, 1970; Khutsishvili, 2006; Liesiö and Salo, 2012; Liu, 2002; Norris, Pilsworth, & Baldwin, 1987; Ruan et al., 2001; Sirbiladze, 2009a, 2009b, 2010a, 2010b, 2013; Sirbiladze et al., 2003; Sirbiladze and Gachechiladze, 2005; Sirbiladze and Sikharulidze, 2003; Sirbiladze, Ghvaberidze, Latsabidze, & Matsaberidze, 2009; Sirbiladze, Sikharulidze, & Sirbiladze, 2010; Sirbiladze, Khutsisvili, & Dvalishvili, 2010; Sirbiladze et al., 2011; Wu et al., 2010; Yager, 2002, 2007 and others).

Nowadays it has become crucial to create informational-expert methodologies that, apart from objective databases, also use the knowledge of experienced experts (financial managers and others), which we call the knowledge base. Literature published in the past decade proposes the application of fuzzy-statistical models, neural and fuzzy-neural networks and genetic algorithms when evaluating credit risks (Chen, 2007; Finlay, 2010; Hoffmann, Baesens, Mues, Van Gestel, & Vanthienen, 2007; Kahraman, Ruan, & Tolga, 2002; Lee and Chen, 2005; Li and Ho, 2009; Malhotra and Malhotra, 2002; Sirbiladze et al., 2003; Sirbiladze, Khutsisvili, et al., 2010; Yu, Wang, & Lai, 2009 and others). All of the above-mentioned approaches are based on the objective databases and expert data.

2. On the three-stage decision-making methodology of evaluating investment projects

When there is little or no objective data to make an investment decision, experienced expert-managers are commissioned to solve the problem. In that case, the knowledge and intellectual activity of experts yield expert data. Trustworthy evaluations based on such data can be prepared and analyzed only by applying informational-expert methodologies.

Such situations have often to be dealt with in developing countries. The authors of this paper, who reside in one of the developing countries, propose to apply the combination of two fuzzy-statistical methods for credit scoring and the solution of a bicriteria discrete optimization problem when a decision on an optimal investment in several projects has to be made. For illustration, in our case this approach ensured a more precise evaluation of investment decision risks and gave a chance to use the expert data provided by the group of experts of the Investment Fund.

When an applicant for credit submits the business-plan to the Investment Fund or a bank, the first thing experts have to do is to investigate the applicant's credit repayment capacity. In particular, they check certain factors that are essential for granting credit. The set of factors is determined by the group of experts representing the Investment Fund or a bank.

Out of the submitted projects usually based on more or less objective data the experts select a small number of projects with insignificant credit risks. They further perform re-evaluation in order to obtain more precise data within the selected set of projects and pick out the most trustworthy ones. Considering the procedure, the decision support methodology, which employs the experts valuations, should involve the following stages:

- applying the method based on the analysis of both objective and expert data in order to condense the experts' knowledge;
- applying the method which is well-suited for processing solely expert data.

The authors of this paper have experience in applying heuristic and fundamental methods to the solution of decision-making problems in which both objective and expert data are used (Khutsishvili, 2006, 2009; Sirbiladze, 2009a, 2009b, 2010a, 2010b, 2013; Sirbiladze and Gachechiladze, 2005; Sirbiladze and Sikharulidze, 2003; Sirbiladze et al., 2003, 2009, 2011; Sirbiladze, Khutsisvili, et al., 2010; Sirbiladze, Sikharulidze, et al., 2010). By comparing various methods and evaluating their reliability, the authors decided on the two methods, which will be discussed below, and applied them successfully to the problem of credit scoring.

In the first stage, the method consists in selecting projects with insignificant or low credit risks among all submitted projects. The selection is made by the expertons method (Kaufmann, 1988, 1992; Sirbiladze, Khutsisvili, et al., 2010) using expert data. The method uses interval (pessimistic–optimistic) evaluations defined by the experts in order to reduce a possibly large number of investment projects requesting for credit. The expert knowledge is thereby condensed and compatibility levels on the set of possible risks for each investment project are constructed. This approach is justified since the number of competing projects may be high in the case of requests for large credit amounts. The method is described in Section 3.2.

In the second stage, the method of possibilistic discrimination analysis developed by the authors (Sirbiladze et al., 2003; Sirbiladze, Khutsisvili, et al., 2010) is used. Its aim is to make more precise decisions as to the competitiveness of the selected projects, to compare the selected projects and perform their qualitative ranking. This method is the possibilistic generalization of the well-known fuzzy discrimination analysis method (Norris et al., 1987). As different from the classical method which works with objective data only, in this paper we propose a further modification of the method of possibilistic discrimination analysis. Using the expert knowledge and experience, the possibility distribution is constructed on the set of all possible decisions (projects), which is used for projects ranking. The description of the modified method is presented in Section 3.3.

In practice, the capital is frequently invested in several projects simultaneously, each of them requiring a different credit amount. However, if the total investment amount has already been predetermined and fixed, it becomes necessary to decide on a share of each project in the initial total investment amount. This is the objective of the third stage of the proposed methodology. Using the decision (recommendation) worked out in the second stage and taking into consideration the total investment amount, the third stage deals with a bicriteria discrete optimization problem (Ehrgott, 2005; Sirbiladze et al., 2009, 2011; Taha, 2011; Wang, 2012) whose solution makes it possible to arrange the most advantageous investment in several projects simultaneously.

Thus, in the third stage, those projects are selected, which possess a maximum possibility level of credit repayment and of gaining a maximum profit for the bank. The method is discussed in Section 3.4.