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Investment project evaluation by a decision making methodology based on type-2 fuzzy sets

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ABSTRACT

Although investment projects supported by the state are extremely important in terms of national policy the projects to be transferred from the common public funds brings with it many problems. Highly transparent and comprehensive evaluation model are required to transfer the public resources to the right investment projects. It is necessary to consider many criteria for the evaluation of an investment project. These criteria are generally subjective and extremely difficult to express in numbers. However, using the fuzzy sets provide huge facilities to decision makers in project evaluation process with linguistic variables and measurement challenges. In this study, a new evaluation model for investment projects have been proposed for development agencies operating in Turkey. To address ambiguities and relativities in real world scenarios more conveniently, type-2 fuzzy sets and crisp sets have been simultaneously used. The proposed model for the investment project evaluation problem composed of type-2 fuzzy AHP and type-2 fuzzy TOPSIS methods. The proposed fuzzy MCDM method consists of three phases: (1) identify the criteria to be used in the model, (2) type-2 fuzzy AHP computations, (3) evaluation of investment projects with type-2 fuzzy TOPSIS and determination of the final rank. To perceive proposed model better, an application with real case data have been performed in Middle Black Sea Development Agency in Turkey. As a consequence of this application, it has been observed that the proposed model have proved effective in evaluation of alternatives in multi-criteria group decision making problems in a broader perspective and flexible fashion.

1. Introduction

Importance of the investment projects carried out by the private sector cannot be ignored for sustainable socio-economic development of countries in the globalizing world. Having a limiting financial resource causes a finance problem so as that private sector realizes the investment projects. In the case of high finance costs, state financially supports private sector to be able realize strategically significant investment projects. Companies continuously make investments for many reasons such as capacity building and technological innovation. Often, there are several alternatives that fit for the purpose of the investment. Among these alternatives, the best option must be chosen for the company. In recent years, many states provide direct financial support to private sector investments in increasing proportions. States promote private sector investments for many reasons such as economic, politic and social. One of the most critical issues of public support is to determine that which projects will be supported. Some of the expected outcomes of the projects with public support are employment increase, prevention of environment damage, national income growth and competitiveness increase. From this point, the answer to the question of which projects should be financed by public support is to choose projects that maximize the benefit criteria mentioned above with the lowest cost.

Even if there are different tools in each country to promote private sector instruments, many countries support investment projects through regional development agencies. Duties of these agencies are as follows [1]:

- Providing technical support to the planning activities and duties of local authorities,
- Supporting the activities and projects ensuring the implementation of regional plan and programs; monitoring and evaluating the implementation process of activities and projects supported within this context and presenting results to the Undersecretariat of State Planning Organization,

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- Contributing to the improvement of the capacity of the region concerning the rural and local development in accordance with the regional plans and programs, and supporting the projects within this extent as well,
- Monitoring other projects implemented by public sector, private sector and non-governmental organizations in the region and considered as important in terms of regional plan and programs,
- Improving cooperation between public sector, private sector and non-governmental organizations to achieve regional development objectives,
- Carrying out research, or having them carried out, concerning the determination of resources and opportunities of the region, acceleration of economic and social development and enhancement of competitiveness, and supporting other research carried out by other persons, organizations and institutions.

In this paper, a new multicriteria decision making (MCDM) model based on Type-2 fuzzy sets is proposed to the current project evaluation system of regional development agencies in Turkey. The proposed model is applied on a real case problem by Middle Black Sea Development Agency in Turkey.

On the other hand, merely considering the dimension of feasibility is not adequate for decision-making. In order for a project to come to life, numerous motives exist and implementation of the Project has various economic, social and environmental impacts. For this reason, evaluation of projects is indeed an MCDM process. The purpose of MCDM is to choose a best candidate from a set of alternatives by means of evaluating multiple attributes of the alternatives [2]. The intent of MCDM methods is to improve the quality of decisions about investment projects involving multiple criteria by making choices more explicit, rational, and efficient [3].

Although economically, evaluation of investment projects are subjectively regarded easy, evaluation of projects on political, social and environmental aspects is complex. Assigning numerical values for evaluation criteria is not always possible. For this reason, in cases where assigning a numerical value is not possible, linguistic variables are used. The fuzzy set theory enables comparison of alternatives by digitizing linguistic variables. A major contribution of fuzzy set theory is its capability of representing vague knowledge. The theory also allows mathematical operators and programming to apply to the fuzzy domain [4].

In the process of decision making, the information about attribute values is usually uncertain or fuzzy due to the increasing complexity of the socio-economic environment and the vagueness of inherent subjective nature of human thinking. This fact has led to many authors to apply the fuzzy set theory [5] to model the uncertainty and vagueness in decision processes [6]. Also the fuzzy set theory is used investment decision making problems. Damghani et al. [7] developed a modular decision support system about choosing the optimum investment instrument in uncertain environment. Karsak and Tolga [8] presented a multi criteria decision-making process that includes fuzzy cash flow analysis to use it for the evaluation of advanced manufacturing system investment. Kahraman et al. [9], in an uncertain economic-decision making environment, to execute the investment analysis in fuzzy based; developed formulas for fuzzy present value analysis, fuzzy future value analysis, fuzzy cost-benefit analysis, fuzzy payback period analysis.

Unlike the published papers a new MCDM methodology based on type-2 fuzzy sets is improved in this paper by integrating crisp and linguistic evaluation together. There are (at least) four sources of uncertainties in type-1 fuzzy logic systems (FLSs) [10]: (i) The meanings of the words that are used in the antecedents and consequents of rules can be uncertain (words mean different things to different people), (ii) Consequents may have a histogram of values associated with them, especially when knowledge is extracted from a group of experts who do not all agree, (iii) Measurements that activate a type-1 FLS may be noisy and therefore uncertain, (iv) The data that are used to tune the parameters of a type-1 FLS may also be noisy. All of these uncertainties translate into uncertainties about fuzzy set membership functions. Type-1 fuzzy sets are not able to directly model such uncertainties because their membership functions are totally crisp. On the other hand, type-2 fuzzy sets are able to model such uncertainties because their membership functions are themselves fuzzy. Membership functions of type-1 fuzzy sets are two-dimensional, whereas membership functions of type-2 fuzzy sets are three-dimensional. It is the new third-dimension of type-2 fuzzy sets that provides additional degrees of freedom that make it possible to directly model uncertainties. Membership functions of Type-1 fuzzy sets are crisp sets. For this reason, in cases where the meanings of criteria are not clear, the evaluators do not hold the same opinions and the setting of evaluation is noisy, type-1 fuzzy sets cannot offer effective decision support. In such cases, type-2 fuzzy sets whose membership functions are type-1 fuzzy sets too enables convenient modeling of problem. If we can use interval type-2 fuzzy sets [11] for handling fuzzy group decision-making problems, then there is room for more flexibility due to the fact that interval type-2 fuzzy sets are more suitable to represent uncertainties than type-1 fuzzy sets [2]. Type-2 fuzzy sets have been successfully applied in decision making process. Erdogan and Kaya [12], proposed an integrated multi-criteria decision-making (MCDM) methodology based on type-2 fuzzy sets for selection among energy alternatives. Then they tried to define a roadmap for Turkey. Erdogan and Kaya [13] used a fuzzy MCDM method based on type-2 TOPSIS to rank the private universities in Istanbul. Erdogan and Kaya [14] proposed a multi criteria decision making (MCDM) methodology based on type-2 fuzzy sets to manage qualitative and quantitative criteria with uncertainties for selecting the best alternative fuel bus for public transportation in Istanbul. Wang et al. [6] presented a new method to handle fuzzy group decision making (GDM) problems based on the ranking values and the arithmetic operations of interval type-2 fuzzy sets (IT2 FSs) and used an example to illustrate the fuzzy GDM process of the proposed method. Wu and Mendel [15] presented a method using the linguistic weighted average and IT2 FSs for handling fuzzy multiple criteria hierarchical GDM problems, Wu and Mendel's fuzzy multiple criteria hierarchical GDM method was to make decisions by means of aggregating the opinions of DMs. Chen and Lee [2] presented an IT2 fuzzy TOPSIS method to handle fuzzy MAGDM problems based on IT2 FSs, and used some examples to illustrate the fuzzy MADM process of the proposed method. Chen and Lee [16] also presented a new method to handle fuzzy MAGDM problems based on the ranking values and the arithmetic operations of IT2 FSs.

In this study, as in many decision making problems, the multi criteria decision making technique is used. Although there are a lot of decision support models in literature, in our study, AHP and TOPSIS methods based on type-2 fuzzy sets due to nature of problem which is subject of our study. Besides, in the model, we used the fuzzy sets and crisp sets at the same time because some evaluation criteria were fuzzy and assessors didn't specify a definite value for some criteria. The proposed model for the investment project evaluation problem, composed of type-2 fuzzy AHP and type-2 fuzzy TOPSIS methods, consists of three phases. In the first phase, the criteria which will be used in project evaluation are determined and the decision hierarchy is formed. In the second phase, criteria used in selection projects are assigned weights using type-2 fuzzy AHP. Project ranks are determined by using type-2 fuzzy TOPSIS method in the third phase.

The rest of this paper is organized as follows. In Section 2, interval type-2 fuzzy sets are briefly introduced. In Section 3, type-2 fuzzy AHP method is briefly reviewed. Type-2 fuzzy TOPSİS method is summarized in Section 4. The proposed decision making methodology based on type-2 fuzzy sets is detailed in Section 5. A real case