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Energy supply planning in Iran by using fuzzy linear programming approach (regarding uncertainties of investment costs)

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Abstract

For many years, energy models have been used in developed or developing countries to satisfy different needs in energy planning. One of major problems against energy planning and consequently energy models is uncertainty, spread in different economic, political and legal dimensions of energy planning. Confronting uncertainty, energy planners have often used two well-known strategies. The first strategy is stochastic programming, in which energy system planners define different scenarios and apply an explicit probability of occurrence to each scenario. The second strategy is Minimax Regret strategy that minimizes regrets of different decisions made in energy planning. Although these strategies have been used extensively, they could not flexibly and effectively deal with the uncertainties caused by fuzziness. ''Fuzzy Linear Programming (FLP)'' is a strategy that can take fuzziness into account. This paper tries to demonstrate the method of application of FLP for optimization of supply energy system in Iran, as a case study. The used FLP model comprises fuzzy coefficients for investment costs. Following the mentioned purpose, it is realized that FLP is an easy and flexible approach that can be a serious competitor for other confronting uncertainties approaches, i.e. stochastic and Minimax Regret strategies.

Keywords: Energy planning; Fuzzy linear programming (FLP); Investment costs uncertainties

1. Introduction

Economics is the scientific study of decisions affecting the allocation of scarce resources between competing ends. In this issue, uncertainty arises whenever a decision can lead to more than one possible consequence.

In economy, nothing is more certain than existence of uncertainty. How many consumers demand commodities, how much prices increase or decrease, how much the interest rate will be and many questions like these are questions that economic decision-makers always encounter. Replying to these questions is not easy for decision-makers, because the future is not clear and obvious to them. They can just estimate the future and so their estimation, undoubtedly, are full of guessing and judgments. Therefore, a decision maker cannot be sure that his current decision will lead to a certain consequence or not.

In Iran, decision and policy making, also, face with a vast domain of uncertainties. Inefficient economic institutions, governmental structure of the economy and numerous legal constraints are the simplest problems in this regard. These challenges make many uncertainties in economic planning, especially in energy planning in Iran.

Among the uncertainties in energy planning, the uncertainty of investment costs is of special importance. Energy sector is the most costly and capital-intensive sector of an economy. Therefore, all the countries intend to expand, develop or rehabilitate their energy sectors, and are trying to provide suitable economic, political, legal and even, cultural conditions for investments.

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Unfortunately, energy investment in Iran always face with a lot of challenges such as the lack of security in private ownership, occurring domestic crises, instability and lack of up-date of the law, various policy makers, etc. These challenges make the investment costs of energy sector uncertain. Therefore, energy planning in Iran cannot follow the goals without considering this kind of uncertainty.

Confronting uncertainties, energy planners often choose two different strategies. The first strategy is stochastic programming and the second is Minimax Regret strategy. Although these strategies have been used extensively, they could not flexibly and effectively deal with the uncertainties caused by fuzziness. Therefore, another strategy that takes fuzziness into account is introduced, i.e. "Fuzzy linear programming (FLP)".

In three past decades, different contributions were published about fuzzy optimization and especially FLP. In despite of this large literature, literature of energy planning by using fuzzy optimization methods is so recent. One of the early published contribution in this field is Canz (1996). This paper summarized the results of the research conducted by the author during the Young Scientists Summer Program (YSSP) in IIASA's[1] Methodology of Decision Analysis (MDA) Project. The basic purpose of the research was to evaluate how the methodology of FLP can support the decision-making process in energy system planning under uncertainty. The research reported in the paper provided an overview of the methods and tools used for supporting decision-making in energy system planning in Germany. It also tried to show how one can improve some elements of FLP applied to a real-world problem by learning from applications of MCMA[2] for decision support and by using software tools developed for MCMA. Also, different papers can be mentioned in this issue such as Gwo-Hshiung et al. (1996), Yang and Lee (1999), Mavrotas et al. (2003) and Borges and Antunes (2003).

Gwo-Hshiung studied Taipower, the official electricity authority of Taiwan, encounterd several difficulties in planning annual coal purchase and allocation schedule. In this study, these concerns were formulated as a fuzzy bicriteria multi-index transportation problem. Furthermore, an effective and interactive algorithm was proposed which combined reducing index method and interactive fuzzy multi-objective linear programming technique to cope with a complicated problem which may be prevalent in other industries. Results obtained in this study clearly demonstrated that this model could not only satisfy more of the actual requirements of the integral system but also offered more information to the decision makers for reference in favor of exalting decision making quality.

[1]International Institute for Applied Systems Analysis.

[2]Multiple criteria model analysis.

The Yang study was concerned with the applications of linear goal programming and fuzzy theory to the analysis of management and operational problems in the radioactive processing system (RWPS). The developed model was validated and verified using actual data obtained from the RWPS at Kyoto University in Japan. The solution by goal programming and fuzzy theory would show the optimal operation point which was to maximize the total treatable radioactive waste volume and minimize the released radioactivity of liquid waste even under the restricted resources.

Mavrotas used a linear programming model, including both continuous and integer variables, which represented energy flows and discrete energy technologies in a large hotel unit as a case study nearby Athens. The model comprised fuzzy parameters in order to handle adequately the uncertainties regarding energy costs. The obtained FLP model was then translated into the equivalent multiple objective linear programming model, which provided a set of efficient solutions, each one characterized by quantification of the risk associated with the uncertain energy costs.

Finally, Borges used an interactive approach to deal with fuzzy multiple objective linear programming problems, which was based on the analysis of the decomposition of the parametric (weight) diagram into indifference regions corresponding to basic efficient solutions. The approach was illustrated to tackle uncertainty and imprecision associated with the coefficients of an input–output energy–economy planning model, aimed at providing decision support to decision makers in the study of the interactions between the energy system and the economy on a national level.

This paper is using a FLP model, including fuzzy objective coefficients of investment costs, that represents the supply energy system of Iran. In this paper, we try to demonstrate the method of application of FLP for optimization of supply energy system of Iran, as a case study. Following this purpose, we realize that FLP is an easy and flexible approach that can be a serious competitor for other confronting uncertainties approaches, i.e. stochastic and Minimax Regret strategies.

2. Current strategies for confronting uncertainty in energy planning

Faced with uncertainties, energy planners often use two well-known strategies. The first strategy is stochastic programming in which energy system planners define different scenarios and apply an explicit probability of occurrence to each scenario. The second strategy is Minimax Regret strategy that minimizes regrets of different decisions made in energy planning.