A Model for IT/IS Project Portfolio Selection in the Presence of Uncertainty: Combination of Fuzzy Multi-Criteria Decision Making and Fuzzy Mathematical Programming

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Abstract. IT/IS represents a substantial financial investment for many organizations. Making IT project portfolio decision is difficult, because long lead times of IT project and market and technology dynamics lead to unavailable and unreliable collected data for portfolio management. This uncertainty has been modeled using fuzzy concepts. We need a collective model that will help decision-makers evaluate potential new investment projects in an easy, cost-effective, and collective manner. Hence, we propose a new approach based on the fuzzy multi-criteria decision model (FMCDM) and a fuzzy binary multi-objective linear programming model, featuring a 2-stage evaluation and selection process with 19 criteria for IT/IS investment. At the first stage, evaluation, all stakeholders in a corporation can decide the relative weights they give to the criteria when they evaluate a new IT/IS project by using linguistic values. Experts can also use linguistic values to evaluate all candidates easily. Only an Excel worksheet is needed to obtain an evaluation result. The results of FMCDM of the aforementioned are treated as input of a fuzzy binary mathematical programming model as coefficients of objective functions, which is the second stage of the proposed model. In the second stage, selection, we have developed a fuzzy binary mathematical programming model in order to find an optimum combination of investment portfolio considering a multi-objective measurement function in three ways: to maximize the benefit, to maximize the confidence level and to minimize the cost of projects in a complete ambiguous condition, when their initial investment costs, profits, confidence levels, resource requirements and total available budgets are assumed to be uncertain. We solve it in Lingo 10.0 through a Branch and Bound algorithm. In this paper, for the first time we have developed a model for IT/IS project portfolio selection in presence of uncertainty that is combination of fuzzy multi-criteria decision making and fuzzy mathematical programming with 19 criteria that is compatible with the nature of IT projects. We conduct a case study to show how this model can be used and discuss the results.

Introduction

Selection of an optimum portfolio is interpreted as capital budgeting which is a common paradigm with enough flexibility for standing in many areas. For example Khalilidamghani and Sadinezhad (2011) present a model for optimum portfolio selection with lowest cost and maximum profit from available investment situations in an ambiguous environment. Chan, DiSalvo, and Garrambone (2005) developed a goal seeking model to address a variation of the capital-budgeting problem and fuzzy rule based system, they proposed a multi-criteria optimization model which considered the diverse functions of the organization. Wang and Hwang (2007) developed a fuzzy portfolio selection model to optimize the R&D portfolio for the risk-averse decision maker in an uncertain R&D environment. Chou et al. (2006) developed a fuzzy multi-criteria decision model approach for Evaluating IT/IS investments with 26 comprehensive criteria.
Model formulation

Suppose that an organization is facing with several investment opportunities in the form of IT/IS projects. In stage one, the proposed FMCDM evaluation method is comprised of the following 9 steps.

Step 1: Form two evaluation teams: a weighting team and a scoring team.

Step 2: Pick appropriate evaluation criteria. We follow Chou and Tzeng (2006) evaluation model and modify it for IT/IS portfolio selection.

![IT/IS Investment Criteria Diagram](image)

Fig. 1: Tzy-Yuan Chou, Seng-cho T. Chou a, 2006.
Step 3: Identify various potential alternative projects and combine them with the existing IT portfolio to form the set of alternative candidates.

Step 4: Set proper linguistic scales (very high, high, medium, low, and very low) and ask the members of the weighting team to give their opinions by pair-wise comparison of evaluation criteria.

Step 5: Convert the linguistic variables into triangle fuzzy numbers as shown in bellow. This gives every-One fuzzy reciprocal matrix.

Step 6: Aggregate the weighting team members fuzzy reciprocal matrices by geometric means and form the final aggregated fuzzy reciprocal matrix. In the same way, aggregate the scoring team member’s opinions by geometric means.

Step 7: Take the geometric row means of every criterion and normalize it to get its local weight. Then, calculate the global importance weight

Step 8: Aggregate all the experts' opinions for each criterion and calculate the final score of all the alternative projects. Every alternative project has a score for each criterion. We multiply each score with the corresponding weight of the criterion and sum up the result to get the final net score of the alternative.

Step 9: These numbers are treated as input of a fuzzy binary mathematical programming model as coefficient of objective function, which is the second stage of the proposed model.

In stage two, suppose we are facing with n projects with the following indices and parameters:

n: The total number of candidate projects

\( v_i \): The fuzzy benefit of candidate project i from the first stage

\( C_i \): The fuzzy cost of candidate project i from the first stage

\( r_i \): The fuzzy risk of candidate project i from the first stage

\( R_i \): The fuzzy confidence level of candidate project i

\( B_t \): The fuzzy budget available for month t

\( C_{it} \): The fuzzy investment cost of candidate project i at month t

\( R_{ikt} \): The number of people with skill k required to implement project i at month t

\( R_{kt} \): The number of people with skill k available to staff projects at stage t

The decision variable of the model is considered as below.

\[ x_i = \begin{cases} 1 & \text{If project i selected for funding} \\ 0 & \text{Otherwise} \end{cases} \]

Due to aforementioned definitions the proposed fuzzy 0–1 programming will be as follow.

\[ \text{Max}\, Z = \sum_{i=1}^{\hat{F}} \overline{v}_i x_i \]  \hspace{1cm} (1)

\[ \text{Min}\, Z = \sum_{i=1}^{\hat{C}} C_i x_i \]  \hspace{1cm} (2)
The objective function presented in Eq. (1) is a function which tries to maximize the benefit of selected projects and Eq. (2) is a function which tries to maximize the confidence level of selected projects and Eq. (3) tries to minimum the cost of selected projects, simultaneously. These objectives are assumed to have the same weights and priorities so they have been combined with a simple additive weight method. The set of constraints (4) and (5), which should be held for all projects and all human resources of the projects, insures that budget and human resources availability is met during the procedure of project selection. We use werner method (1984) for solving this model. For each objective function with the constraint in optimistic (the least requirements and the most availability) and pessimistic (the most requirements and the least availability) situations we will have 9 objective functions with two optimistic and pessimistic situations and one final program for selecting the projects with maximum degree of membership function.

**Experimental result**

In this section, the proposed model is tested in hamkaran system Corporation of Iran. We calculate the Total score of 5 candidate projects in all criteria. The results are reported in Tables 3.

| Project no. | Fuzzy development cost (in millions) | First month | Second month | Third month |
|-------------|--------------------------------------|-------------|--------------|-------------|
| 1           |                                      | (2,2,0.3)   | (30,30,4.5)  | (30,30,4.5) |
| 2           |                                      | (3.3,0.45)  | (50,50,75)   | (45,45,6.75) |
| 3           |                                      | (10,10,1.5) | (75,75,11.25)| (100,100,15)|
| 4           |                                      | (5.5,0.75)  | (65,65,9.75) | (170,170,25.5) |
| 5           |                                      | (20,20,3)   | (85,85,12.75)| (200,200,30) |

Table 2. Required human resources represented by fuzzy numbers for 5 candidate projects

| Project no. | Fuzzy development cost (in work months) | First month | Second month | Third month |
|-------------|----------------------------------------|-------------|--------------|-------------|
| 1           | (6.6,0.6)                              | (72,72,7.2) | (50,50,5)   |
| 2           | (12,12,1.2)                            | (80,80,8)   | (48,48,4.8) |
| 3           | (24,24,2.4)                            | (95,5,9.5)  | (70,70,7)   |
| 4           | (12,12,1.2)                            | (100,100,10)| (70,70,7)   |
| 5           | (32,32,3.2)                            | (120,120,12)| (80,80,8)   |
For the first month company has (22,4,5) million dollar and (40,2,3) expertise for analysis the projects. For the second month company has (120,20,30) million dollar and (200,15,17) expertise for design the projects and For the third month they have (230,50,20) million and (130,4,3) expertise for write code. We run the programs. The results are summarized in table form below:

Table 3. Results of Werner method

| Run | Criteria | optimistic | pessimistic | condition | Selected variable | Objective value |
|-----|----------|------------|-------------|-----------|-------------------|-----------------|
| 1   | benefit  | •          |             | Upper bound | $X_2, X_5=1$      | $V=0.0395$      |
| 2   | benefit  | •          |             | Middle     | $X_2, X_5=1$      | $V=0.0045$      |
| 3   | benefit  | •          |             | Lower bound | $X_i=0$           | $V=0$           |
| 4   | benefit  | •          |             | Upper bound | $X_2=1$           | $V=0.0147$      |
| 5   | benefit  | •          |             | Middle     | $X_2=1$           | $V=0.0004$      |
| 6   | benefit  | •          |             | Lower bound | $X_i=0$           | $V=0$           |
| 7   | C.L.     | •          |             | Upper bound | $X_2=1$           | $V=0.9576$      |
| 8   | C.L.     | •          |             | Middle     | $X_2=1$           | $V=0.0124$      |
| 9   | C.L.     | •          |             | Lower bound | $X_i=0$           | $V=0$           |
| 10  | C.L.     | •          |             | Upper bound | $X_2, X_5=1$      | $V=1.90$        |
| 11  | C.L.     | •          |             | Middle     | $X_2, X_5=1$      | $V=0.0207$      |
| 12  | C.L.     | •          |             | Lower bound | $X_2=1$           | $V=0.0020$      |
| 13  | Cost     | •          |             | Upper bound | $X_i=0$           | $V=0$           |
| 14  | Cost     | •          |             | Middle     | $X_i=0$           | $V=0$           |
| 15  | Cost     | •          |             | Lower bound | $X_2=1$           | $V=0.0042$      |
| 16  | Cost     | •          |             | Upper bound | $X_i=0$           | $V=0$           |
| 17  | Cost     | •          |             | Middle     | $X_i=0$           | $V=0$           |
| 18  | Cost     | •          |             | Lower bound | $X_2, X_5=1$      | $V=0.0042$      |
| 19  | All      | Both       | Both        | All        | $X_2, X_5=1$      | $\alpha=0.146$ |

As is clear finally second and fourth projects selected for funding with maximum degree of membership function ($\alpha$) equal to 0.146.

Conclusion

We developed a collective model that will help decision-makers evaluate potential new investment projects in an easy, cost-effective, and collective manner. As mentioned before the main core of the proposed model is a fuzzy mathematical programming which is involved finding optimum solution for a NP-hard problem (i.e. multi-dimensional knapsack) and the corporation be satisfied by the results.

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