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Project portfolio optimization in upstream oil industry in knowledge based organization, "Case study: Tehran energy consultants company"

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Abstract

The oil and gas industry is probably the most important industry in the world. By growing demands of energy, the need for executing oil and gas projects becomes more than ever. Mega projects in this industry have certain characteristic such as being investment intensive, multi objective, owners, investors, vendors and contracts, risk and uncertainties and etc. Nowadays, knowledge-based organizations play important role in oil and gas industry. Due to the expansion and growth of project-oriented knowledge-based organizations, one of the important issues in these organizations is the optimal selection of the project portfolio. The problem is how to choose the optimal project portfolio. In this research you will find how to establish an optimal project portfolio and with respect to organization constraints. At the end, the methodology is applied as a case study in TEC company-an active project-oriented knowledge-based organization in upstream oil and gas industry in Iran.

Keywords: Upstream Oil Industry, Knowledge Based Organization, Project Portfolio optimization, Integer Linear Programming.

Paper Type: Original Research

1. Introduction

The oil and gas industry are possibly the most important industry in the world (Werner et al., 2016). By growing demands of energy, the need for executing oil and gas projects becomes more than ever (Merrow, 2011). The characteristics of the oil and gas projects mega projects include requirements of enormous capital investment cost (CAPEX), multi objectives, multi owners and investors, multi contractors, multi vendors, huge amount of workforces from multi countries, compounding of emerging technologies, risks and uncertainties of projects, logistic challenges, and unparalleled environmental risk (Tanaka, 2014). Nowadays, knowledge-based organizations (KBO) play important role in oil and gas industry. According to statistics released by the Vice-Presidency for Science and Technology, from 2015 to October 2018, 4,559 KBO have been approved by the working group for evaluation and qualification of KBO and institutions, of which 300 of them are active in the field of oil and gas. Project-oriented organizations are always trying to do their projects in the best way. However, projects face various limitations. One of the most important constraints among projects is resource constraint and one of the most important tasks in organizations is resource allocation. On the other hand, due to the expansion and growth of project-oriented KBO, one of the important issues in these organizations is the optimal selection of the project portfolio. The problem is how to choose the optimal project portfolio in project-based KBO to meet the organization's constraints (Engwall and Jerbrant, 2003). Knowledge-based companies are among the organizations whose activities are based on knowledge, and in this regard, the innovations and inventions that take place in these companies are based on this. Innovations in the form of universities and knowledge-based companies lead to economic growth, which is one of the most important findings in the macroeconomic debate and is fully applicable in countries. Considering the increase in expansion of large projects and the desire of various organizations to define their economic solutions as projects, leveling and allocating resources has become the main concern of senior managers of any project-based organization. Given the expansion and growth of knowledge-based or technology-based organizations and the importance of timely projects in these organizations, as well as cost and budget constraints, it is necessary to provide a way to efficiently allocate organizational resources to the project portfolio and from it where in knowledge-

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based or technology-based organizations this issue is less addressed. The objectives of this research are (I) Determining the stages of projects entering the portfolio of KBO, and (II) Selecting the optimal project portfolio in project-oriented KBO with respect to organization constraints. The purpose of this paper is to identifying the differences and similarities of KBO with other organizations in project concepts, resources and project portfolio, determining the stages of projects entering the portfolio of KBO, selecting the optimal project portfolio in project-oriented KBO. The paper is focused on two research questions: (Q1). What is included in the project portfolio in oil and gas project-oriented KBO? And what are the steps to enter this portfolio? (Q2). In oil and gas project-based KBO, how can an optimal project portfolio be selected that meets the organization's constraints?

2. Literature review

2.1. Project, program, and portfolio concepts

A project is a temporary endeavor undertaken to create a unique product, service, or result. A program is related projects, subsidiary programs, and program activities that are managed in a coordinated manner to obtain benefits not available from managing them individually (PMI, 2021). A portfolio is a collection of projects, programs, subsidiary portfolios, and operations managed as a group to achieve strategic objectives (PMI, 2017). Program management is defined as the application of knowledge, skills, and principles to a program to achieve the program objectives and to obtain benefits and control not available by managing program components individually (PMI, 2021). Portfolio management is the centralized management of one or more portfolios to achieve strategic objectives. It is the application of portfolio management principles to align the portfolio and its components with the organizational strategy (PMI, 2021). Companies often engage in many projects at the same time. A key managerial task is to assign resources to all of these projects (besides doing daily work) and as a result, management across projects (Project Portfolio Management - PPM) is critical to company performance (Blichfeldt and Eskerod, 2008). The basis of portfolio theory was proposed by Harry Markowitz in the 1950s. Markowitz's portfolio model is an analysis method based on estimating average values and random variables. The purpose of this method of investment portfolio formation is to make the best selection of assets to be acquired, taking into account the approved risk/return criteria. Archer and Ghasemzadeh’s (1999) definition of project portfolios is a group of projects that are carried out under the sponsorship and/or management of a particular organization. Henceforth, Blichfeldt and Eskerod define PPM as the managerial activities that relate to (1) the initial screening, selection and prioritization of project proposals, (2) the concurrent reprioritization of projects in the portfolio, and (3) the allocation and reallocation of resources to projects according to priority (Blichfeldt and Eskerod, 2008). According to research about project portfolio selection methods from 1999 to 2019 they are categorized in to financial methods, probabilistic methods, option pricing, scoring methods, combinatorial optimization, behavioral methods, mapping approaches, real options, integrated methods, information gap theory, information gap theory, scenario-based approach (Danesh et al., 2018). The method which is applied in this paper is a combinational optimization.

2.2. Oil and gas industry

The oil and gas industry are usually divided into three major sectors: upstream (or Exploration and Production - E&P), midstream, and downstream. This research only focuses on the upstream sector of oil and gas industry. The upstream segment of the oil and gas industry contains exploration activities, which include creating geological surveys and obtaining land rights, and production activities, which include onshore and offshore drilling. The life cycle of a hydrocarbon field is shown in Figure 1 (Alleyne and Alexander, 2018).

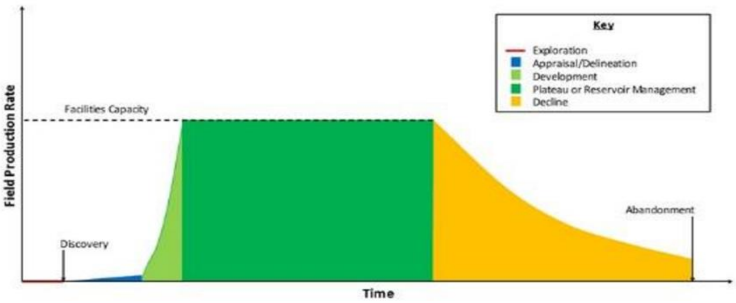

Figure 1. The life cycle of a hydrocarbon field

Oil and gas exploration encompasses the processes and methods involved in locating potential sites for oil and gas drilling and extraction. Early oil and gas explorers relied upon surface signs like natural oil seeps, but developments in science and technology have made oil and gas exploration more efficient. Geological surveys are conducted using various means from testing subsoil for onshore exploration to using seismic imaging for offshore exploration. Energy companies compete for access to mineral rights granted by governments by either entering a concession agreement, meaning any discovered oil and gas are the property of the producers, or a production-sharing agreement, where the government retains ownership and participation rights. Exploration is high risk and expensive, involving primarily corporate funds. The cost of an unsuccessful exploration, such as one that consisted of seismic studies and drilling a dry well, can cost $5 million to $20 million per exploration site and in some cases is much more. However, when an exploration site is successful and oil and gas extraction is productive, exploration costs are recovered and are significantly less in comparison to other production costs (Downey, 2009). Oil and gas production is one of the most capital-intensive industries: It requires expensive equipment and highly skilled labors. Once a company identifies where oil or gas is located, plans begin for drilling. Many oil and gas companies contract with specialized drilling firms and pay for the labor crew and rig day rates. Drilling depths, rock hardness, weather conditions and distance of the site can all affect the drilling duration. Tracking data using smart technologies can help with drilling efficiency and well performance by providing real-time information and trends (Raymond and Leffler, 2017). While every drilling rig has the same essential components, the drilling methods vary depending on the type of oil or gas and the geology of the location (Conaway, 1999). Table 1 shows an example of these divisions.

Table 1. Different types of projects in upstream oil and gas industry

Oil and gas exploration and production	Production support	Ancillary service
Exploration	Power Plant	Clubs and dining halls
Drilling	Water supply / gas supply	Stadiums
Construction of industrial units and oil and gas production plants	Telecommunications	Organizational house
Repairs in oil and gas factories and industrial units	Heavy vehicles and mobile construction machinery	Office building
Construction of oil and gas pipelines	Road construction	Green space

2.3. KBO

The term knowledge-based companies with this concept, is rarely found in international texts. The term knowledge-based company (organization) in theoretical terms mostly refers to companies that are learners and creators of knowledge and use knowledge, whether tacit or explicit knowledge, to develop their products and technologies. In fact, this concept refers more to established organizations that use the processes of creating and applying knowledge to advance their business (Nonaka, 1998). In other words, in international texts, the concepts of KBO, knowledge-creating companies, learning companies and intelligent organization have been used in theoretical terms as the synonym of KBO (KBO) (Bavkhani, 2016). A review of KBO of scientific articles and theoretical foundations also shows that there is a wide range of concepts related to small and medium enterprises that focus on technology. Rickne and Jacobson have identified the concepts associated with these companies as follows (Rickne and Jacobsson, 1999).

1. New technology-based companies
2. Technology-based small and medium-sized firm
3. New enterprise in high-tech industry
4. Attractive small company and new venture

The term KBO, or relatively similar terms, is a relatively new term in the world's management and economic literature. So many countries have not yet provided a precise and clear definition of it. Studies about the literature of the subject in foreign scientific sources shows that the concept of KBO, equivalent to what has been proposed in our country, can be found among scientific articles with different expressions; phrases like knowledge-intensive organization or business, knowledge-intensive Subject Matter Expert (SME), technology- based firm, and innovative small firm. Many organizations and firms have come to believe that for greater success and effectiveness in the world nowadays economic field, they must become a KBO. Nevertheless, few of these organizations learned how to act in order to become knowledge-based and how to create change in them. Many of them think that the more knowledge is the focus of their production and services, the more knowledge-based they are. Opponents of this view argue that being knowledge-based of organizations should not be determined by their products and services because it's just seeing the tip of the iceberg. The main part of being knowledge-based of an organization is its technical knowledge, how to use the knowledge and why it is used. KBO and its characteristics: A review of the existing texts in this field shows that there is no single definition of KBO and different people with different approaches have conceptualized this type of organization. Some researchers have defined KBO as equivalent to learning organization; KBO have the characteristics of learning organizations, but the most important point in these organizations is the creation of wealth and value creation by relying on resources and knowledge products that are materialized in the form of software, technologies and technical and specialized services with high added value. Based on the definition provided in the law on protection of knowledge-based companies and institutions and commercialization of innovations and inventions, knowledge organizations are institutions that aim to synergize science and wealth, develop a knowledge-based economy, achieve scientific and economic goals (including the development and application of inventions and innovations), and commercialize results of research and development (including design and production of goods and services) are active in the field of high technologies and high added value. In this regulation, the characteristics of knowledge-based goods are described as follows: 1. It is high and medium to high technology field 2. It has technical complexity and its production and continuation require research and development 3. Its major added value is Due to technical knowledge and innovation. KBO are organizations whose survival depends on the creation of knowledge through research and their flourishing on knowledge innovations. KBO will need knowledgeable managers and experts. The knowledge-oriented groups, nuclei, and individuals that make up the cells of a KBO must have the same general characteristics and capabilities of a KBO; that is, the ability to create knowledge through research and turn it into innovation

3. Methodology

The research methodology includes 6 phases:

1.Identifying the project portfolio selection decision making criteria based on literature review.
2. Using Fuzzy Delphi Method (FDM) (Liu and Chen, 2007) to analyze the interdependence and relationships of decision-making criteria and screening major criteria.
3. Using Best Worst Method (BWM) (Rezaei, 2014) for determining the weight of each the decision criteria.
4.Evaluating projects priority based on Weighted Aggregates Sum Product Assessment (WASPAS) method (Zavadskas et al., 2012).
5. Problem modelling by using planning models with respect to organization limitation and constraints
6. Solving the problem by using the proposed model.

The study accounted for in this paper should be seen as a rather exploratory study. At first, an initial list of project portfolio selection criteria, obtained from literature review of previous studies was provided.

3.1. Fuzzy Delphi Method (FDM)

In order to logically reduce the number of decision criteria which were identified previously, FDM which proposed by Liu and Chen (2007) is applied to screen the major decision criteria in projects among the others, based on SMEs opinions. The steps of FDM are represented as follows.

Step 1. Designing questionnaire: the first step of this method is to design the FDM questionnaire. In order to fuzzify the linguistic answers of SMEs, a triangular fuzzy spectrum is employed for the five-point Likert scale of the following Table 2.

Table 2. Triangular fuzzy numbers and related linguistic terms in FDM

Fuzzy Number	Linguistic Term	Fuzzy Scale
1	Very Unimportant (VU)	(0,0,0.25)
2	Unimportant (U)	(0,0.25,0.5)
3	Neutral (N)	(0.25,0.5,0.75)
4	Important(I)	(0.5,0.75,1)
5	Very Important (VI)	(0.75,1,1)

The geometrical diagram of the scale is presented in Figure 2.

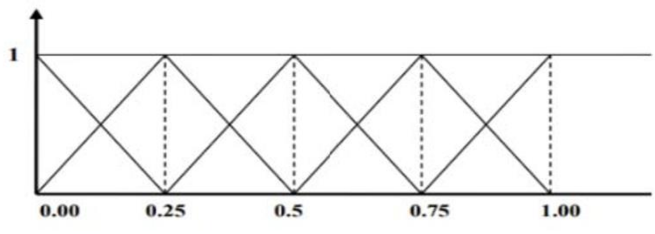

Figure 2: The geometrical diagram of the Fuzzy scale

Step 2. Participants selecting: parallel the Traditional Delphi Method, the number of respondents should be more than 8, and less than 20 experts. The participant for this research should be chosen among the project managers who are currently managing project portfolios in the position of consultant in upstream oil and gas industry.

Step 3. Fuzzification: at this step, the expert opinions are collected and fuzzified. The importance level of indicator i, given by SME j, is shown as Equation (3-1).

$$fij = (lij, mij, uij) \quad \text{where } i = 1,2, \ldots, n \quad nj = 1,2, \ldots, k \qquad (1)$$

Step 4. Aggregating data: in this step, the data which gathered from SME`s should be aggregated. The aggregation importance level of i is represented in following equation.

$$fi = (\min(lij), k\sqrt{\prod mij}, (uij)) \qquad (2)$$

Step 5. Defuzzification: now, every fuzzified numbers should defuzzify to a definitive value (si). There are several defuzzification method. Equation (3-3) represents the defuzzification value:
si = li + [ui − li + (mi − li)]3 = li + mi + ui3 (3)
Step 6. Selecting or eliminating: at final step, decision criteria will be screened out by comparing to threshold α, which is considered 0.6 in this study.so:
If Si > α, then the criteria j should be selected, otherwise it should be eliminated. (4)

The FDM threshold schematic diagram is shown as below.

$$A = \begin{matrix} a1 \\ a2 \\ \ldots \\ am \end{matrix} \begin{pmatrix} p11 & p12 & \ldots & p1n \\ p21 & p22 & \ldots & p2n \\ \ldots & \ldots & \ldots & \ldots \\ pm1 & pm2 & \ldots & pmn \end{pmatrix} \quad (5)$$

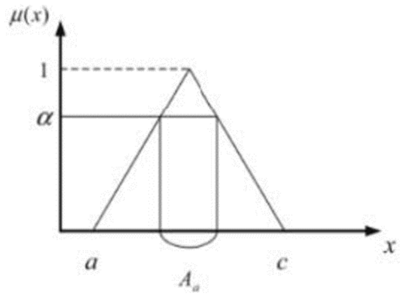

Figure 3. Schematic diagram of FDM threshold

3.2. Best-Worst Method (BWM)

After identifying main decision criteria by screening, it is supposed to determine the weight of each criterion. In this study the BWM proposed by Rezaei (2014), is used to calculating the weight of the criteria. In the following, this method is fully described. The BWM was first proposed by Jafar Rezaei in 2014 to solve Multi criteria decision-making problems. It is a pairwise comparison-based method. According to this method, the best and the worst criteria are identified by the decision-maker. After that, Pair wise comparisons are conducted between each of these two criteria (best and worst) and the other criteria. In order to determine the weights of different criteria a maximin problem is then formulated. By using the same process, the weights of the alternatives with respect to different criteria are obtained. The final scores of the alternatives are derived by aggregating the weights from different sets of criteria and alternatives, based on which the best alternative is selected.
Suppose there are n criteria to be weighted, and we want to compare these criteria in pairs using a ratio of 1/9 to 9. The resulting matrix would be: Among them, a_{ij} represents the relative preference of criteria i to criteria j, where $a_{ij} = 1$ shows that i and j are equally important, and $a_{ij} > 1$ shows that i is more important than j, and aij = 9 shows that i is extremely important to j. aji shows the importance of j to i. In order to make matrix A reciprocal, it is required that $a_{ij} = 1/a_{ji}$ and $a_{ii} = 1$, for all i and j. Consider the reciprocal nature of the matrix A. To obtain the complete matrix A, $n\,(n-1)/2$ pairwise comparisons are required. In the following cases, the pairwise comparison matrix A is considered to be completely consistent if $a_{ij} \times a_{jk} = a_{ik}$. By running pairwise comparison a_{ij}, the decision-maker expresses the direction and strength of the preference i over j. Steps of the BWM are shown as follows.
Step 1. Determine a set of decision criteria.
In this step, we consider that the criteria $\{c1;\ c2;\ \ldots\ldots;\ cn\}$ should be used to make a decision.
Step 2. Determine the best (e.g., most ideal, most important) and the worst (e.g. least ideal, least important) criteria. In this step, the decision maker generally determines the best and the worst criterion. No comparison is made at this stage.
Step 3. Determine the priority of the best criterion over all other criteria using a number from 1 to 9. The resulting best-to-others vector would be:
$AB = (aB1, aB2, \ldots, aBn)$ (6)
where aBj gives the preference of the best criterion B over criterion j. It is clear that $aBB = 1$.
Step 4. Determine the priority of all criteria over the worst criterion using a number between 1 and 9. The others-to-worst vector result would be:
$AW = (a1W, a2W, \ldots, anW)T$ (7)
Where ajW indicates the preference of criterion j over the worst criterion W. It is clear that $aWW = 1$.

Step 5. Find the optimal weights ($w1*, w2*, \ldots, wn*$). The optimal weight for the criteria is the one where, for each pair of wB/wj and wj/wW, we have wB/wj = aBj and wj/wW = ajW. To satisfy these conditions for all j, we should find a solution where the maximum absolute differences $|wB / wj - aBj|$ and $|wj / wW - ajW|$ for all j is minimized. Considering the non-negativity and sum condition for the weights, the following problem is resulted:

$$Min\ maxj \{ \left| \frac{wB}{wj} - aBj \right|, \left| \frac{wj}{wW} - ajW \right| \} \quad (8)$$

$St.$

$$\sum_j Wj = 1 \quad (9)$$

$$W \geq 0, for\ all\ j \quad (10)$$

The previous Problem can be transferred to the following problem:

$$\min \xi \quad (11)$$

$$\left| \frac{wB}{Wj} - aBj \right| \leq \xi, \text{ for all j} \quad (12)$$

$$\left| \frac{wj}{wW} - ajW \right| \leq \xi, \text{ for all j} \quad (13)$$

$$\sum_j Wj = 1 \quad (14)$$

$$W \geq 0, for\ all\ j \quad (15)$$

By solving the problem, the optimal weight ($w1*, w2*, \ldots, wn*$) and $\xi*$ will be obtained. In a few decision-making problems, we have an alternative value i with respect to criterion j (pij). For example, imagine a vehicle selection problem where fuel consumption is a criterion, and we've got statistics approximately the fuel intake of all of the alternative. In the same vehicle selection decision-making problems, however, values pij aren't available. For example, imagine the identical vehicle selection where color is a criterion and there are automobiles with distinctive colors (not values). In case of the latter problem, where values pij aren't available, the aforementioned process is likewise completed for the alternatives (evaluating alternatives towards every criterion) to fine pij (the weight of alternative i with respect to criterion j). At any rate, we then actually calculate the overall rating of alternative i as $Vi = \Sigma i = 1n\ WjPij$. By sorting the values of $Vi\ \forall I$, the best alternative is identified. In the subsequent section, by using $\xi*$, we present a consistency ratio. It will become clear that, the bigger the ξ*, the higher the consistency ratio, and the much less reliable the comparisons become.

3.3. Weighted Aggregates Sum Product Assessment (WASPAS)

At this stage, projects are evaluating by the decision criteria obtained from previous steps. In order to do so, the WASPAS introduced by Zavadskas et al., (2012) is employed. The WASPAS method is a unique combination of the two MCDM approaches: Weighted Sum Model (WSM) and the Weighted Product Model (WPM). The input information of the method is expressed in terms of the matrix of alternatives and attributes, which is based on information received from the decision maker, as shown below:

As it expressed earlier, in order to use this method, it is required to develop a decision/evaluation matrix, R = [rij]m×n where rij is performance of ith alternative with respect to jth criterion, m is the number of alternatives and n is the number of criteria. For making the performance measures dimensionless and comparable, all the elements of the decision matrix will be normalized by using the two equations as follow:

$$r^*ij = \frac{rij}{\max_i rij}; \quad i = 1, \ldots, m, \quad j = 1, \ldots, n \quad (16)$$

$$r^*ij = \frac{\min_i rij}{rij}; \quad i = 1, \ldots, m, \quad j = 1, \ldots, n \quad (17)$$

Where $\bar{r}ij$ is the normalized value of rij.

In WASPAS method, based on two criteria of optimality a joint criterion of optimality is sought. The first criterion of optimality, i.e., criterion of a mean weighted success is similar to WSM method. It is a popular and well accepted MCDM approach applied for evaluating a number of alternatives with respect to a set of decision criteria. Based on WSM method. the total relative importance of ith alternative is calculated as follows:

$$Qi(1) = \sum \bar{r}\,ij\ wj, nj = 1 \quad (18)$$

Where wj is weight (relative importance) of jth criterion.

Any other way, confirming to WPM method, the total relative importance of ith alternative is evaluated by applying the equation as follows:

$$Qi(2) = \prod(\bar{r}\,ij)nj = 1wj \quad (19)$$

A joint generalized criterion of weighted aggregation of additive and multiplicative methods is then proposed as follows:

$$Qi = 0.5i(1) + 0.5Qi(2) = 0.5 \sum \bar{r}\,ijwjnj = 1 + 0.5 \prod(\bar{r}\,ij) = 1wj \quad (20)$$

Arrange to have expanded positioning precision and accuracy of the decision-making process, the total relative significance of ith elective will be developed (Zavadskas et al., 2012) as underneath:

$Qi = \lambda Qi(1) + (1 - \lambda)Qi(2) = \lambda \sum \bar{r} ijwjnj = 1 + (1 - \lambda) \prod(\bar{r}\, ij)nj = 1wj \quad , \lambda = 0{,}0.1, \dots ,1$ (21)

The feasible alternatives are presently ranked based on the Q values and the best elective alternative has the highest Q value. In the above equation, when the value of λ equals to 0, WASPAS method is transformed to WPM, and when λ equals to 1, it becomes WSM method. The optimal values of λ for a given decision-making problem, can be determined while searching the following extreme function:

$\lambda = 62\big(Qi(2)\big)62\big(\mathrm{Qi}(1)\big) + 62(\mathrm{Qi}(2))$ (22)

The variances $ϭ2(Qi(1))$ *and* $ϭ2(Qi(2))$ can be computed using the equation as follows:

$62(Qi(2)) = \sum = wj2(\bar{r}\, ij), nj = 1$ (23)

$62(Q\ (2)) = \sum(\prod(\bar{r}\, ij)wj\ wjnj = 1(\bar{r}\, ij)wj(\bar{r}\, ij)(1 - wj)2nj = 162(\bar{r}\, ij)$ (24)

The estimates of variances of the normalized initial criteria values are calculated as follows:

$62(\bar{r}\, ij) = (0.05\bar{r}\, ij)2.$ (25)

Variances of estimates of alternatives in WASPAS method depend of the variances of WSM and WPM approaches as well as on the value of λ. It may be beneficial to compute the optimal values of λ and assure the maximum accuracy of estimation.

3.4. Problem modelling

In this section, a Linear Programming model (LP) is represented which selects the projects that have the maximum profit and the goal is the total profit of each project set and seeks to maximize objective function Z. Limitations of this model are the limitations of the budget and human resources required for each project. This section focuses on the formulation of the project selection model. This model considers m candidate projects, and each project j has a related decision variable$x1, x2, x3\ \dots, xm$, which are a member of positive integers (Davoudi, 2021):

$If\ xi = 0, then\ the\ project\ is\ not\ chosen$ (26)

$If\ xi \neq 0, then\ xi\ project\ of\ type\ it\ is\ chosen\ Maxz = C1X1 + C2X2 + \cdots + CmXm$

Z is the criterion for maximizing the profit of the total portfolio projects and the profit of the selected projects. In order to include the effect of project selection criteria in the linear programming problem, the objective function coefficients (Cj) are defined as result of multiplying the profit of each project in the weight obtained by WASPAS method. This criterion (Z) is in line with the goal and strategy of the organization and the limitations are functions that are described due to the availability of resources for project implementation that can meet some of the requirements of the project. The constraint functions can be defined as follows:

$\sum 1 \sum aijxjmj = 1ni = 1 \leq bi$ (27)

ai shows the use of resource ith in project j, bi is the total amount of ith resource and n are the number of resources. To solve any LP problem by the simplex algorithm, it has to be converted to a form called standard form. So, by converting the problem to the standard form the project which set the optimal portfolio will achieve.

4. Case studied

Compiled project portfolio Selection criteria related to evaluating and assessing various project in various industry sectors are shown in Table 3. To refine these criteria based on requirements of upstream oil and gas projects, they are reviewed by a group of SMEs. The result of aggregation, defuzzification and acceptance or elimination of each criterion is shown in Table 3. If the crisp value of a criterion is more than 4 the criteria is selected as a main factor, otherwise it will be eliminated. The criteria are sorted in descending order.

Table 3. Fuzzy and crisp values of criteria

Criteria code	Fuzzy value			Crisp value	Criteria code	Fuzzy value			Crisp value
	L	M	U			L	M	U	
C14	6	6.806532091	7	6.602177364	C28	3	3.851286194	5	3.950428731
C4	5	6.509617309	7	6.169872436	C23	3	3.729921228	5	3.909973743
C12	5	6.492967581	7	6.164322527	C24	2	3.489165669	6	3.82972189
C17	5	6.225654554	7	6.075218185	C26	3	3.41909832	4	3.473032773
C2	5	6.022661144	7	6.007553715	C3	2	3.395260229	5	3.465086743
C6	4	5.117183125	7	5.372394375	C19	2	3.24119379	5	3.413731263
C9	3	5.669363313	7	5.223121104	C20	1	3.569873612	5	3.189957871
C15	3	4.935569327	7	4.978523109	C5	2	3.176106064	4	3.058702021
C16	3	4.741252862	7	4.913750954	C1	2	3.094118411	4	3.031372804
C11	4	4.517565526	6	4.839188509	C10	1	2.874222187	4	2.624740729
C27	4	4.322035104	6	4.774011701	C25	1	2.685940365	4	2.561980122
C22	3	3.930210341	5	3.97673678	C18	1	2.588737826	4	2.529579275
C8	3	3.87394864	5	3.95798288	C21	1	1.990546775	3	1.996848925
C7	3	3.851286194	5	3.950428731	C13	1	1.80134844	3	1.933782813

In the next step, the chosen project portfolio selection criteria through FDM method are demonstrated as Table 4.

Table 4. The major project portfolio selection criteria

Code	Criteria	Description of criterion
C14	Return of capital	Net return is a function of development cost analysis and benchmarking international oil prices. Using discounted cash flow techniques, such as Net Present Value (NPV), Internal Rate of Return (IRR) and Investment Efficiency Ratio or Utility Index, the higher these economic indicators, the better the development project
C4	Project time horizon	The time horizon is defined in two dimensions: project life and start-up time. There are usually preferred projects that are both short-lived and fast-paced in the short term
C12	Upgrading the level of technology	This indicator shows how effective the project is in increasing the technological capabilities of the organization
C17	Capital cost	Organizations undertake projects that are commensurate with the amounts of resources and credits available to them
C2	Hardware	The amount of access to equipment and facilities required for the project in the organization or outside the organization
C6	Degree of transparency and simplicity of the project	Simplicity and complexity of the project is one of the main factors in selecting and prioritizing the project because in this case there is less uncertainty and unknown issues.
C9	Possibility of existence of technical and legal challenges in project	Some projects may face technical or legal challenges that may not be solvable or have significant financial implications.
C15	Ease of project financing from inside and outside the organization	Predicting the credit required to design and execute the project and the possibility of providing it is one of the most important factors in selecting and prioritizing projects. Naturally, projects that can be easily financed from within the organization as well as from outside the organization by government grants, loans, etc. have a higher priority
C16	Economics of the project	The ratio of profit to cost or in other words the profitability of the project is an important criterion in selecting and prioritizing projects
C11	Upgrade staff capabilities	This indicator shows how effective the project is in increasing the expertise and skills of the staff
C27	Competitive advantage	Competitive advantage refers to a capability, which acquires from the attributes and resources to perform in a higher level within the industry

In order to apply the BWM for determining the weight of each the decision criterion, the following 5 steps were taken:

Step 1. The set of decision criteria is $\{C14, C4, C12, C17, C2, C6, C9, C15, C16, C11, C27\}$

Step 2. Best criteria chosen by SME is "Return of capital" and worse criteria is "Upgrade staff capabilities"

Step 3. Determine the priority of the best criterion over all other criteria using a number from 1 to 9. The cumulative result of Best-to-others vector would be:

$AB\ =\ (5.344, 4.271, 4.343, 3.995, 9, 3.395, 1, 4.301, 4.581, 4.101, 7.066)$

Step 4. Determine the priority of all criteria over the worst criterion using a number between 1 and 9. The Others-to-Worst vector result would be:

$AW\ =\ (4.384, 4.566, 5.276, 5.738, 1, 6.698, 9, 4.783, 4.786, 5.598, 2.682)\ T$

Step 5. the optimal weights $(w1\,*, w2\,*, \ldots, w11\,*)$. The optimal weight for each criterion is found and shown in table 5.

Table 5. Optimal weights of the PPS criteria

Code	Criterion	Weight
C14	Return of capital	0.0640
C4	Project time horizon	0.0800
C12	Upgrading the level of technology of the organization	0.0780
C17	Capital cost	0.0856
C2	Hardware	0.0240
C6	Degree of transparency and simplicity of the project	0.1007
C9	Possibility of existence of technical and legal challenges in project	0.2803
C15	Ease of project financing from inside and outside the organization	0.0795
C16	Economics of the project	0.0746
C11	Upgrade staff capabilities	0.0834
C27	Competitive advantage	0.0484

In order to evaluate projects priority based on WASPAS method, the input information of the method is expressed in terms of the matrix of alternatives (projects) and attributes (decision criteria), which is based on information received from the decision maker, as shown below:

$$A \begin{bmatrix} 3.014253.953342.043292.043292.097444.034353.043263.014251.969351.969353.014256.069114.081975.027281.969357.939425.984653.046703.079491 \\ .969356.085033.014254.034352.210065.673263.176114.000003.225876.362587.024634.000006.350665.014426.682115.208694.019413.896745.580003. \\ 976604.081974.081973.276094.981483.079496.986893.079495.000003.468754.899594.981483.000005.000002.757115.168524.165624.420132.293054. \\ 081973.195124.576226.085033.291983.751873.127435.000004.165626.607766.000006.830484.081976.423445.000004.000003.000004.165626.402615.00000 \end{bmatrix}$$

For making the performance measures dimensionless and comparable, all the elements of the decision matrix will be normalized. Result is shown in table 6.

Table 6. Normalized decision matrix

Run No.	C17	C9	C14	C12	C4	C12	C6	C11	C15	C16	C27
W	0.0834	0.0856	0.2803	0.1008	0.0801	0.0640	0.0788	0.0243	0.0795	0.0747	0.0484

Results of Q-values are presented in Table 7.

Table 7. Q-values

Eq 3. Q1	C17	C9	C14	C12	C4	C12	C6	C11	C15	C16	C27
1	0.0834	0.0440	0.2803	0.1008	0.0363	0.0328	0.0174	0.0243	0.0642	0.0747	0.0484
2	0.0414	0.0520	0.1583	0.0862	0.0801	0.0640	0.0320	0.0130	0.0768	0.0439	0.0360
3	0.0623	0.0503	0.1786	0.0762	0.0560	0.0572	0.0246	0.0118	0.0795	0.0429	0.0197
4	0.0592	0.0436	0.1993	0.0876	0.0579	0.0406	0.0219	0.0160	0.0622	0.0491	0.0368
5	0.0360	0.0707	0.1285	0.0543	0.0660	0.0476	0.0392	0.0080	0.0638	0.0434	0.0253
6	0.0312	0.0856	0.1285	0.0456	0.0558	0.0494	0.0788	0.0093	0.0774	0.0508	0.0197

Eq 4. Q1	C17	C9	C14	C12	C4	C12	C6	C11	C15	C16	C27
1	1.0000	0.9445	1.0000	1.0000	0.9386	0.9580	0.8879	1.0000	0.9831	1.0000	1.0000
2	0.9433	0.9581	0.8519	0.9844	1.0000	1.0000	0.9315	0.9849	0.9972	0.9611	0.9858
3	0.9760	0.9554	0.8813	0.9722	0.9717	0.9929	0.9125	0.9827	1.0000	0.9594	0.9574
4	0.9717	0.9439	0.9088	0.9860	0.9744	0.9713	0.9041	0.9899	0.9806	0.9692	0.9868
5	0.9323	0.9837	0.8036	0.9397	0.9846	0.9812	0.9465	0.9734	0.9826	0.9602	0.9691
6	0.9212	1.0000	0.8036	0.9232	0.9715	0.9836	1.0000	0.9770	0.9978	0.9716	0.9574

By using equation project is ranked, the result is presented in table 8.

Table 8. Projects ranking

Project number	Project type	Q	Project rank
1	MDP	0.7739	1
2	Advisory	0.6704	2
3	MC	0.6470	4
4	Technical Service	0.6635	3
5	ENGG	0.5732	6
6	Supervision	0.6122	5

In this point we want to solve the problem. Tehran Energy Consultant (TEC) projects are divided into six categories: Master Development Plan (MDP), Advisory, Management Contract (MC), Technical Service, Engineering and Supervision. The goal of this research is to determine how many projects from each category are to take at one time to work with the limitations and maximize profit. The numbers and the constraints are shown in table 9.

Table 9. Summary of problem constraints and formulation

Name	Projects					
	MDP	Advisory	MC	Technical service	ENGG	Supervision
Profit	3250000	450000	1060000	325000	669000	178000
Expense	1500000	200000	250000	90000	130000	50000
Geologist	12	8	7	9	5	3
Project management team	7	10	8	10	5	6
Drilling	10	8	7	9	3	2
HSE	6	8	5	6	3	2
Engineer	15	10	7	10	8	6
Construction	13	15	10	15	10	8

In TEC Company, total available resources are 2900000 expenses, 24 geologists, 25 project team members, 17 HSE-man, 30 engineers, and 40 construction experts. Let us build the mathematical model. Let x1 be the number of MDP projects to taken, x2 be the number of advisory projects to taken, x3 be the number of MC projects to taken, x4 be the number of technical service projects to taken, x5 be the number of engineering projects to taken, and x6 be the number of supervision projects to taken. The LP model for the above resources is built as follow:

$Max\ z = 2503552.4X1 + 300308.9X2 + 700146.5X3 + 400568.1X5 + 100071.8X6$
S.t.
$12X1 + 8X2 + 7X3 + 9X4 + 5X5 + 3X6 \leq 24$
$7X1 + 10X2 + 8X3 + 10X4 + 5X5 + 6X6 \leq 25$
$10X1 + 8X2 + 7X3 + 9X4 + 3X5 + 2X6 \leq 25$
$6X1 + 8X2 + 5X3 + 6X4 + 3X5 + 2X6 \leq 1715X1 + 10X2 + 7X3 + 10X4 + 8X5 + 3X6 \leq 30$
$13X1 + 15X2 + 10X3 + 15X4 + 10X5 + 8X6 \leq 40$
$1500000X1 + 200000X2 + 250000X3 + 90000X4 + 130000X5 + 50000X6 \leq 2900000$
$X1, X2, X3, X4 \geq 0$

The result of solving the above LP model through the simplex algorithm is 1, 0, 1, 0, 1, 0 for X1 to X6 respectively.

4. Conclusion

In this paper, a Linear Programming (LP) model for optimal selection of the project portfolio in knowledge-based organizations (KBO) was suggested. The proposed model contains three fundamental elements from decision making knowledge: (I) Fuzzy Delphi Method (FDM) to evaluate the relationships of decision-making criteria and screening them, (II) Best Worst Method (BWM) to determine the weight of each criterion, and (III) Weighted Aggregates Sum Product Assessment (WASPAS) method to evaluate discrete projects. To demonstrate applicability and effectiveness of the model, it was applied as a case study in Tehran Energy Consultant (TEC). The case included 28 criteria and six projects. As a result of solving LP model, despite the outcomes achieved from WASPAS method which declares project 2 is prior than project 3 in regard to project portfolio selection criteria, the optimal project portfolio based on available budget and human resources of the company, includes projects1,3, and 5. The same happened for project 4 and 5. This model not only does select project portfolio based on project selection decision criteria, but also maximizes the profit of the selected portfolio with respect to organizational resources constraints. For the future researches, the paper recommends: (1) Employing another combination of decision-making techniques instead of FDM-BWM-WASPAS, e.g., FDM-ROC-COPRAS or FDM-SWARA-ARAS, (2) Extending the proposed model in probabilistic environment, (3) Applying the proposed model for real-world cases with bigger number of criteria.

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