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The Model of Upstream Investment Portfolio in the Mature Regions

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ABSTRACT

Portfolio models can serve as an assessment tool for the optimal assignment of capital between the potential investment projects in the various conditions for upstream companies. This process is crucial for any company if it wants to balance the short-term goals and seeks to maximize long-term value of the company. The paper aims to present a practical model of forming oil upstream company's portfolio. The unique feature of this model is an individual approach to investment plan forming in a context of three types of projects: Exploration, oil production and infrastructure projects. This is due to the individual approach which is used for comparison of all projects by using of universal set of indicators. Suggested model uses the multi-criteria selection mechanism by means of aggregating the key estimating indicators into the final project rank score. In that way the task of forming investment project's portfolio of upstream company is a linear programming problem that is solved by simplex method. In the paper the model forms consolidated investment portfolio that takes into account decision makers' preferences in setting of limits for resources.

Keywords: Simplex Method, Project's Ranking Indicator, Decision-making Mechanism, Optimization Model, Investment Portfolio, Upstream Company
JEL Classifications: O13, L22

1. INTRODUCTION

According to the IEA (International Energy Agency, 2018), since 2014 the global oil demand has been on an upward trend. Thus, over the past 4 years, the demand has been increasing by 6% from 94 to 100 mb/d. In order to keep its market share, Russian oil upstream companies are looking for ways of oil production increasing. However, it is difficult to implement due to significant investment reduction in 2014-2016 years that affected to the overall level of oil production. Consequently the intensive investments both in the greenfields and the brownfields are essential to production increase. It should be noted that the most brownfields in Russia are on the last stage of reservoir development or contain tight oil and gas. For the production of such oil companies have to increase the investments into the drilling of horizontal and directional wells and their reconstruction. Moreover, the long-term expansion program of oil companies involves the expansion of hydrocarbon resource base due to the implementation of capital-intensive and high-risk exploration projects.

Taking into account the unstable price situation on the raw material market the upstream companies should analyze the objects for investment thoroughly. Within this framework many investments can become unprofitable due low oil prices. According to the experts of the PwC, "in the long-term oil companies need to make their portfolios profitable against low break-even prices"

(PwC, 2018). In this context there is a concern about quality mechanism applying which helps to form an investment plan for the upstream companies. It should be based on modern optimization model that reduces costs and achieves company's strategic goals. The reason for introducing the model into the investment activities of oil companies is inspired by the following necessities:
1. Value of the investment portfolio increasing;
2. The investment risks reduction;
3. Quality selection of investment projects;
4. Achieve a balanced allocation of resources between the projects.

Moreover, the international studies (Project Management Institute, 2016 and Project Management Solutions Inc., 2009) show that the implementing the mechanism of the company's investment plan forming allows to carry out more projects with high return of equity, increases corporate goals hitting probability and raises the profit and return on investments. Therefore, the issue of developing a model for the projects' portfolio formation is actual for all oil producing companies.

The research of Product Development Institute showed that the best result in portfolio management is obtained in case of simultaneous application of several management methods (Product Development Institute Inc., 2001). According to this study, the most popular methods of portfolio management are: Economic methods with financial indicators, a method of portfolio strategy matching, a bubble chart, a scoring model and a questionnaire for selecting and ranking projects in the portfolio.

Russian scientists from the higher school of economics conducted a comparative analysis of approaches to portfolio management and proposed a universal algorithm for choosing the best portfolio management method, taking into account the particualarities of projects (degree of indicator's uncertainty, interdependence), their number, specifity of project selection criteria (Anshin and Barkhatov, 2012).

According to this algorithm, the most appropriate portfolio management methods for upstream companies are linear and non-linear programming methods, ranking models combined with a strategy matching method and a bubble diagram as a portfolio visualization tool. This set of methods is explained by the project portfolio specifics in this industry: Companies usually have a large number of projects with clearly defined indicators (characteristic of low uncertainty) and a strong requirement for the decisions formalization.

Analysis of the recently developed investment portfolio formation model shows that the most common instruments for solving the problem of upstream companies' portfolio formation engaged in production are risk theory and Markowitz 'portfolio selection theory (Sharpe, 1989; Sopilko et al., 2017). For example, Bulai and Horobet described a model that formed the efficient frontier of portfolio assets. It minimizes the risks taking into account the distribution of the expected return on the portfolio. The model is focused on mature regions with unproductive deposits (Bulai and Horobet, 2018).

Risk management is a hot issue for portfolio optimization exploration. So Vashkevich et al. (2017) proposed to use the probabilistic approach, which allows estimating a number of key project parameters (oil initially in place, production profile, economic parameters, etc.) in order to form the optimal exploration portfolio. Another method of risk inventory is the implementation of real option conception. It allows forming the portfolio using the opportunity to defer an investment (Aziz et al., 2017; Dias, 2004; Huang et al., 2018).

Other researchers (Xue et al., 2014; Khalova et al., 2019) have proposed a model that analyzes the operational premium and risk tolerance during project portfolio forming. The issue portfolio diversification correlating with investors risk tolerance is considered. They have also proved that the best portfolio option is one that primary consists of assets with a high operating premium.

The group of scientists from Sinopec institute of petroleum exploitation and development have worked out a mixed integer programming model for projects selecting. They offer to decision-maker to choose and combine the restrictions and criteria for projects selecting at their own discretion. As the result, one of 300 variants of optimization model was chosen for implementation (Fan et al., 2018). On the one hand, this option provides a more flexible approach to portfolio optimization, but, on the other hand, it covers up the danger of finding an irrational portfolio option in terms of production, as it may reflect a mistaken view of the company's capabilities.

A very interesting approach to finding the optimal portfolio of investment projects is proposed by a group of scientists from China (Tang et al., 2017). The possibility of applying the combination of the discounted cash flow method and the trinomial tree model of the real option approach is considered. The authors also propose to take into account some uncertainties in the decision-making process, such as oil prices, the exchange rate and the political environment. Other specialists are focused on integrated optimization model creating that compares different production strategies (Rahmawati et al., 2012; Nazarova et al. 2017; Nazarova et al. 2019). The main feature of such kind of model is that it simulates the complete value chain from production to sale.

Yurua and Dongkun (2009) have proposed an optimal model of multi-stage investment solution for exploration and development for oil companies. This model takes into account operating costs, production rate, reserve-production ratio and decline rate. The peculiarity of this model lies in the fact that it combines two models: A model of investment in exploration and proven reserves growth, and the model of investment in development and production. As the result, the goal of the optimal model is to find a rational balance of investment in geological and investment in development over a long time period.

Reviewed models are of current oil industry interest. However, they don't focus on the problems of investment operations in the mature region, which consist in the investment projects realization inside the brownfields (appraisal project, well drilling, capital repairs or infrastructure construction). They mostly work with the fields in general, but not with the investment projects at the fields. Considering the fact that the majority of fields in the mature region are brownfields which are at a late stage of development, the overall investment activity consists in the implementation of the isolated complexes of investment operations at the fields. These sets of operations shouldn't be hidden by the field management program, otherwise it is difficult to monitor their effectiveness. It is also important that they compete for investment. That is why detailed assessment and selection should be provided per investment projects at the fields. Moreover, it is advisable to conduct the selection according to the principle of diversifying the types of investment at the fields. This is due to incorrect comparison of projects with different target orientation. The described approach is implemented in our model that makes it different from the existing models. We propose to classify the investment projects in the model in order to form an optimal portfolio for real investments in oil company. The implementation of these separate projects in the model allows us not only to find out inefficient investment decisions, but also to choose the best option for production from the field.

2. METHODOLOGY OF THE RESEARCH

The upstream real investment portfolio is a combination of multidirectional projects grouped with a goal of their effective management in the context of limited investment resources. It is important to note that the project is considered as an investment measure limited in time and budget; implemented within one or several oil-gas fields. Each project is individual both in its essence and in technical parameters. That is why in our model we offer to group the projects in 3 classes:

1. Exploration projects are projects focused on the extension. These projects may include seismic investigations, mining, geophysics and resources assessment;
2. Production projects. This type of project can include drilling and production of well infrastructure development or workover (sidetracking, radial drilling, switching to another horizon, etc.);
3. Infrastructure projects are projects that provide oil and gas fields with the necessary infrastructure. This type of project may include construction of interfield infrastructure, reconstruction and modernization of infield and interfield infrastructure objects.

The indexes, formulas and the model presented in the paper were proved on the basis engineering analysis and research.

The process of portfolio formation is carried out separately within each class of projects. After analyzing the indexes used to evaluate the investment projects in world practice (Cong et al., 2013; Wright, 2017) and general practice of Russian oil companies, an individual set of indicators was determined for each project class taking into account their specificity. Based on them the comparison and selection of projects is carried out. The selected indexes express the most important indicators that assess the efficiency of each class of the investment projects. Thus, we use the indexes connected with the reserves increment and Unit cost of reserves increment for exploration projects, the economical indexes (Net present value [NPV], Internal rate of return, Payback period, Profitability Index) for production projects, and the indexes of utility for oil fields (PDE, RF) while estimating the infrastructure project. The full description of indexes is presented in the Table 1.

As can be seen from the Table 1, each index has a personal weighting factor (Wi). The value of index's weight means its significance in cumulative project evaluation system. Weight distribution is conducted and based on the expert opinion according to the best practices of oil and gas majors in terms of each project class. The indexes that have the most weight are key criteria at the moment when upstream company makes the decision on project implementation.

It is important to note that exploration projects have a geological risk of unconfirmed reserves. It should be taken into account during project cost-effectiveness analysis. The best way to introduce it is to replace NPV with Expected monetary value (EMV) which shows the sum of project NPV in all possible options, weighted by the probability.

It also should be mentioned that NPV of infrastructure projects and EMV of exploration projects are negative, because these projects do not increase the company net profit. But they have another goal - to expanse the resource base and to ensure normal working process of extracting and transporting oil to the oil pumping station. Thus, these indexes will have a negative value in evaluating the results of the model, but it is more important to pay attention to the dynamics of their changes (that should be positive).

In the process of the best portfolio variant forming, all projects are ranked by the indexes in the model ("Indexes" are shown in the Table 1). Ranking is made by allocating the highest rank to the project with the best index value. Thus, each project has several ranks by several indexes. The main advantage of ranking is that it helps to solve the problem with different units amounts. There is no subjective factor when ranking projects, as projects compete in absolute values of indicators. Then the final project rank score is being formed (Formula 1):

Table 1: Estimating indexes of the investment projects in upstream companies

Index	Definition	Unit	Wi	Project class
RI	Reserves increment	Mn. tons	0.5	Exploration projects
RIC	Unit cost of reserves increment	$/tons	0.2	Exploration projects
NPV or EMV	Net present value or Expected monetary value	Mn. USD	0.2/0.3	Production projects or exploration projects
IRR	Internal rate of return	%	0.2	Production projects
PbP	Payback period	Years	0.2	Production projects
PI	Profitability index	Decimal quantity	0.2	Production projects
PROD	Oil production	Th. tones	0.2	Production projects
PDE	Percent of decline in field efficiency caused by infrastructure project execution	%	0.5	Infrastructure projects
RF	Number of fields relevant to the infrastructure project	Pieces	0.5	Infrastructure projects

Wi: Weighting factor

$$A_j = \sum_{j=1}^{n} W_i \times a_{ij} \quad (1)$$

where A_j – final project rank score of j-th investment project;
W_i – weighting factor of i-th index;
a_{ij} – rank of j-th investment project by i-th index.

The final project rank score takes into account the given ranks (aij) and index's Wi shown in the Table 1.

The model maximizes the objective function (Formula 2) and puts the limitations (Formulas 3-7, described in the Table 2).

$$F = \sum_{j=1}^{n} A_j \times x_j \quad (2)$$

where F – the objective function of company investment portfolio;
x_j – binary variable of j- th project.

Thus, a general limitation in the model is investment restriction. This is due to the need to form the company's investment program in the medium term. As far as exploration projects are concerned, we propose to use the restriction of Formula 4, which controls increment cost in project reserves. Non less important criterion for production projects is the restriction in Formula 6 since oil producers annually establish a forecasted hydrocarbon production plan.

It is worth noting that the main advantage of this model is a financial affordability, good feasibility and ease of results interpretation.

For piloting the model and analyzing its feasibility, a projects database of Russian middle-sized upstream company was used. It included 39 projects to be implemented in the medium term (the next 3 years). Under the circumstances of economic recession, the most actual task was to improve the portfolio in accordance with limited resources. In that way the model analyzed the investment projects and the optimization proposals. The model included technical-and-economic indicators of projects' full life cycle and companies' investment limits within 3 years (2019-2021 years). Economic indicators of the project were discounted at the rate of 15% (the set rate of the company). The projects data used by model is presented in the Table 3.

The task of the investment portfolio formation model is a linear programming problem solved using a simplex method in Microsoft Excel.

3. THE RESULTS OF RESEARCH

We implemented the developed model which analyzed 39 projects. The purpose was to include the most attractive ones in portfolio: 14 of them were exploration projects, 11 – production projects, 14 – infrastructure projects. The final score of project ranking score was calculated for each project, and then the limitations were inserted according to the project's classes.

As a result, an optimal portfolio model was formed in which 31 projects involved. It is shown in the Figure 1.

Figure 1 shows the cumulative portfolio of a company's investment projects. Each project class has its own label. The best projects are located in the lower right corner as they have the most attractive technical-and-economic indicators (aggregated into the project rank score) and the lowest investment costs over 3-year period.

Table 2: Model's confinement conditions

Limitations	Definition	Project class
$x_j = \begin{cases} 0, \text{to leave out the project} \\ 1, \text{to include the project} \end{cases}$ (3)	Binary variable that denotes the project selection (x_j=1) or not (x_j=0) when forming portfolio. Also, it presents the project integrality while including it in portfolio (i.e., infeasibility of slicing up the project)	Exploration projects, Production projects, Infrastructure projects
$RIC_j \le RIC_{max}$ (4) where RIC_j - unit cost of j-th project`s reserves increment RIC_{max} – maximum set value of reserves increment cost	The limitation of maximum allowable value of project reserves increment cost	Exploration projects
$\sum_{j=1}^{n} Capex_j \le Capex_{max}$ (5) where $Capex_j$ – j-th project investment in a set period of time $Capex_{max}$ - maximum allowable value of company investment costs in a set period of time	Investment restrictions in a set period of time (usually 2-3 years)	Exploration projects, Production projects, Infrastructure projects
$\sum_{j=1}^{n} PROD_j \le PROD_{min}$ (6) where $PROD_j$ – j-th project oil production $PROD_{min}$ – minimum set oil production volume from the projects included in the portfolio	The limitation of minimum set oil production volume	Production projects
$x_{j'} + x_{j''} \le 1$ (7) where x_j' and x_j^''- variables of two alternative projects	Conflicting projects (in case when there are the alternative variants of oil-pool development, company should choose the most beneficial one)	Production projects

Table 3: Technical-and-economic indexes of the investment projects

Project class	Project No.	RF, Pieces	Ri, Mn. tons	PROD, Th. tones	RIC, $/ tons	NPV/EMV, Mn. USD	IRR, %	PI, Dec. quant.	PbP, years	NPV of relevant fields, Mn. USD	PDE, %	Capex 2019-2021, Mn. USD	Total capex, Mn. USD
Exploration	1	1	1.5		21	−8						20	32
	2	1	0.8		20	−4						8	16
	3	1	1.1		14	−3						8	15
	4	1	1.2		32	−5						14	38
	5	1	0.2		27	−3						5	6
	6	1	2.3		28	−5						13	64
	7	1	1.3		19	−7						8	25
	8	1	0.4		64	−11						5	26
	9	1	0.6		14	−7						8	8
	10	1	0.6		20	−3						5	13
	11	1	0.3		22	−4						4	6
	12	1	0.1		24	−4						2	2
	13	1	0.2		25	−9						2	5
	14	1	0.4		21	−3						3	8
Production	15	1		279		10	16	3	4			9	11
	16	1		621		30	24	6	6			4	10
	17	1		410		33	18	5	2			11	16
	18	1		98		10	17	5	4			2	4
	19	1		1112		89	37	7	3			8	24
	20	1		820		130	49	18	2			2	9
	21	1		140		39	23	28	6			2	2
	22	1		704		76	59	15	3			4	9
	23	1		518		48	21	15	4			4	6
	24	1		107		11	15	3	1			4	10
	25	1		300		9	16	2	3			10	14
Infrastructure	26	3				−20				300	7	5	6
	27	2				−6				78	8	1	1
	28	7				−43				400	11	21	21
	29	2				−3				180	2	0,2	0,3
	30	5				−26				270	10	7	7
	31	3				−16				80	20	5	5
	32	2				−7				129	5	1	1
	33	3				−27				832	3	4	6
	34	10				−63				944	7	27	34
	35	2				−41				388	11	11	11
	36	4				−23				380	6	4	4
	37	2				−8				34	24	2	2
	38	3				−37				410	9	9	10
	39	2				−21				146	14	4	4

PbP: Payback period, PI: Profitability index, NPV: Net present value, EMV: Expected monetary value

The obtained results allow to visualize the existing investment opportunities and express the unfavorable projects for the company.

Also, as can be seen on the Diagram the 8 projects (marked by red color) were excluded from the portfolio as they have the least attractive technical and economic indicators. Due to the projects' selection the total portfolio of NPV has almost doubled from 69 to 131 million USD while the level of the investment costs in the 3-year period decreased by 28% from 269 to 195 million USD. It is shown in the Figure 2.

The results of model implementation are shown in the Figure 2. According to these results, the total level of the investments dropped dramatically after portfolio optimization. Moreover, the model has selected the portfolio option that is the closest to the set value of the investment restriction (indicated by the red line). We also can see that after model implementing the cumulative NPV of the portfolio almost doubled.

4. DISCUSSION

The obtained results indicate the effectiveness of the model application aimed to form the optimal investment portfolio of oil producing company. It is worth noting the simplicity of the model realization in Excel. It also stands to mention the visibility and the effortless interpretation of the model results. As far as large volume

Figure 1: The Scheme of upstream projects portfolio allocation

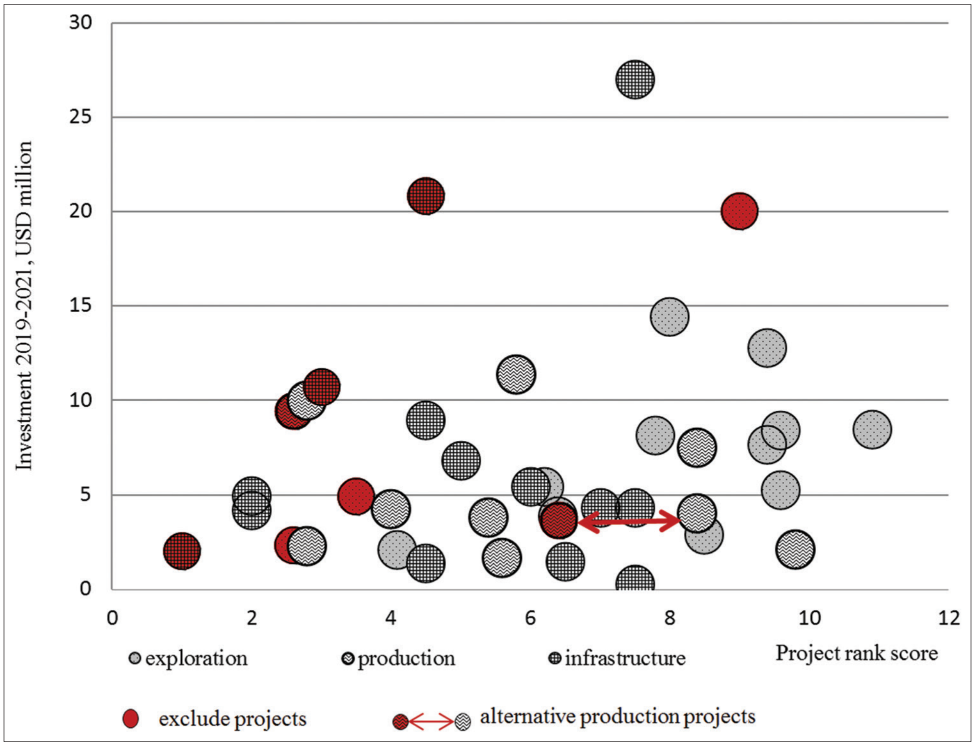
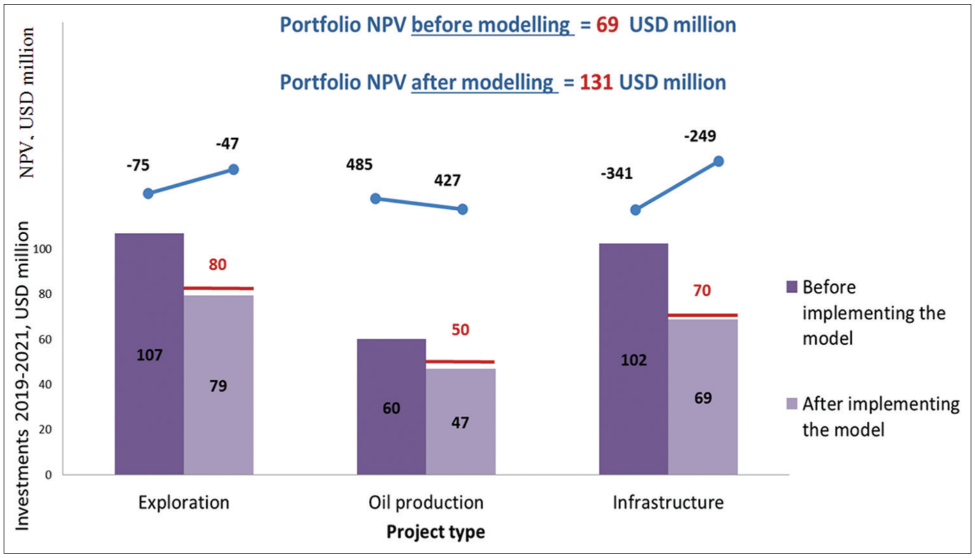


Figure 2: Portfolio optimization results



of project data is in the model, it can operate in accelerated mode because it uses the built-in solver tool that applies techniques from the operations research.

You may be alerted by the inclusion in the portfolio of an infrastructure project with a record high investment. But it all comes down to the value of indexes by which the project was ranked. First of all, it has a maximum (among projects in portfolio) number of oil fields associated with it (10 fields with a weighted-average equal to 3-4 fields). Secondly, the percentage reduction in field work efficiency caused by implementation of infrastructure project is 6.7% (which is below the weighted-average of 10%). As a result, the project is the best in its class and it is advisable to be realized.

The results obtained and described in this paper are quite important for understanding the process of distributing investments between oil projects. Moreover, they promote the formation of a decision-making mechanism in the context of limited resources.

As a part of our further research we are still working on the inclusion of the intermediate factor in projects' implementation in the model. This factor directly impacts on volatility of project's technical and economic parameters. Thus, if the project is at the initial stage of its realization, upstream company should plan the investment costs in the light of high probability of the project parameters changing.

5. CONCLUSIONS

The presented model is suitable for optimizing the medium-term investment plan in upstream companies. It takes into account the specifics of oil investment projects. The model generates a project's ranking indicator by evaluating a number of criteria. It seeks to form a portfolio of projects with a maximum rank indicator. It also allows imposing the limitations like investments, maximum allowable reserves costs, minimum oil production volume, etc. The model is extremely useful for operating with a large number of projects, because in this case the manual selection by several factors it a is very difficult task for decision makers. In these circumstances the decision maker's choice is not so obvious. Consequently, the model is the most convenient tool for the formation of optimal investment portfolio.

Obtained results show the possibility of multi-criteria selection of investment projects in the portfolio: The model excluding 20% of projects was proposed. That leads to the investment decreasing by 28% in the 3-year period and a twofold increase the portfolio NPV. Thus, the model implementation promotes the formation of a decision-making mechanism in the context of limited resources. At the same time, we consider a potential direction for further development of the model which includes an intermediate factor in the project's model.

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