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Systematically Dynamic Model-Building Approach of Oil Company

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Abstract: This study presents scientifically practical aspects of systemically dynamic approach appliance in the investment activity management of oil company. There was built a structural model of oil company which allows computing the level of its economic growth, its inconsistency and stability as well as developing election procedures and grounding activities on its level increase. The model includes following subsystems: oil prospecting and oil finding, oil extraction, repair works, oil transportation. The model is meant for system development optimization of investment portfolio of the oil and gas company.

Key words: Systems dynamics, portfolio investment, oil company, oil exploration and production, oil transportation, system and dynamic approach

INTRODUCTION

For the moment oil and gas industry appears to be fundamental and the most dynamically developing economic industry in the Republic of Kazakhstan. Investments play special role in this industry. From the perspective of market requirements investments are consisting of: cash and cash equivalents, written down value, cost of land franchise, rights to possessions which can be estimated by cash equivalent, etc.

Investment classification on investment targets subdivides them on direct and portfolio investments. In general investment portfolio shall mean a complex of several capital projects, operated as a unit. The portfolio can simultaneously include real means (land, realty, machines, equipment, etc.) and financial assets (securities, equity units, currency, etc.) and intangible assets (intellectual property rights, research and development of a project) and nonfinancial means (gem stones, collectibles) (Askinadzi and Maksimova, 2005).

Investing activity of oil company concerns next segments: geologic exploration and oil development, oil refining and distribution (Akopov, 2006). These segments shall further compose a foundation of investment portfolio of oil company. Key portfolio management problems of investment projects of oil company are: accounting complexity of key indicator's mutual interaction of oil company activity, the necessity of simultaneous project reviews over all business segments, the necessity of infrastructural peculiarities allowance of oil company (transportation and distribution system), etc.

Making decisions under portfolio set-up demands allowance of a number of various factors, relevant to the dynamic of oil company's cost. In this case, the substantial aid would be rendered by simulating model which basis is system dynamics.

According to reseacher Akopov (2004), system dynamics is a method of simulating modeling, based on system representation at a high level of abstraction as traffic flows, aggregates, auxiliary variables and sub models with their elements".

From the mathematical point of view the model of system dynamics is described by the system of first order differential equation of Cauchy. In terms of a work there was represented a model, affecting all core activity of oil company.

A review of recent researches and papers: For the first time ever the systematically dynamic approach was proposed in works of Forester (1961) in the 50's for modeling activities of complicated production systems, instantiated by the availability of backward communication. This approach has got its further development in works of West scientists Sobotka (2000)

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and Riddals *et al.* (2000). In the study of Saeed (2014) the Forrester's approach is up for discussion for economic problems solving and it demands rethinking of economic practice.

The study of Agyapong-Kodua and Weston (2011) shows the methods of system dynamics modeling in iThink using cause-and-effect relations. The study of Iusuf *et al.* (2016) undertaks the studies of sensibility under extreme conditions, on developed systematically dynamic model in order to provide security, confidence of cause and effect relation.

The study of Sterman (2002) presents how successfully accept system dynamics for solving of business and logistical problems.

The study of Uekhar *et al.* (2016) presents multi-sectorial model of population dynamics with limited resources including key concepts from the sphere of market-driven economy and prices

The study of Milosz and Kozhanov (2016) presents the procedure of dynamic building models of technical and engineering systems with the use of system dynamics method.

Papers of Akopov (2006) were centered around systemically dynamic approach in the investment activity management of oil company. Tonkih and Ostaltseva (2012) have constructed a model of oil industry enterprise economic growth, built on the basis of indicator principles of dynamic hierarchy and dynamic comparability.

Systematically dynamic modeling of complicated economical and engineering systems: The modeling of investing processes is possible with the help of various methods as follows:

- Systematically dynamic modeling (Forrester J., Universal dynamics in 1961)
- Mathematical modeling in economics (Medvedev A.V., Mathematical modeling in economics of regional investment processes in 2007)
- Stochastic optimization, games theory (Uriasev S.P., Adaptive algorithms of stochastic optimization and games theory in 1990)
- Analysis of ordinary differential equation and partial differential equation (Mizohat S., Theory of equations with partial derivatives in 1977)
- Stochastic differential equations (Levakov A.A, Stochastic differential equations in 2009)
- Real options theory (Budylin I.A., The appliance of real options for estimation of investment projects in 2007)
- Comparative statics of equal balance (Dudov S.I., Vygodchikova I.Iu, Kuptsov S.N., Mathematical methods in the economy in 2014)
- Calculation constructive method (Orehov A.I., Economic research approaches, I., in 2009)

Under the conditions of management decision high cost peculiar to oil company as the instrument for investment portfolio optimization system development for oil and gas company, there has been chosen the simulating modeling, one of direction of which is system dynamics. The method of system dynamics exercises specific instrument, allowing reflecting cause-and-effect relations between system elements and their dynamics.

It should be also pointed out, that success is related to development of informational systems of dynamic modeling, particularly to famous software programssuch as AnyLogic, Powersim and VisSim, supporting the conception of system dynamics (Osorgin, 2012; Sidorenko, 2001).

The AnyLogic program has modern graphical user interfaceand permits the use ofJava languagefor model development. Very broadly, the basic conception of the use of this system modeling can be presented by description of behavioral rules of separate activities in convenient graphical format. The model is consisted of active objects (which respond to its environment developments as well as undertake certain actions while do not wait for a seamless access to it), each of them has its own rules of conduct and interacts through explicit interfaces (Fig. 1).

Powersim is meant for construction of continuous and partially discrete models. The main aim of Powersim language is the description generation or symbolic-form model of imaginary or real system. Any model is consisted of set of interrelated elements, described as variable. Model elements and relations between them determine model structure. It's been said, that the model is built if all variables and relations between them are determines, i.e., if model structure is provided. A powersim package is the tool of continuous model creation. Powersim are suitable for users which demand for continuous model building which want to study the complicated system of notations systems dynamics. Let us consider the design pattern of systematically dynamic model which will be of the form as shown in Fig. 2.

As it is submitted in the Fig. 2 in the object description there is pointed out the development process of investing activities of oil company.

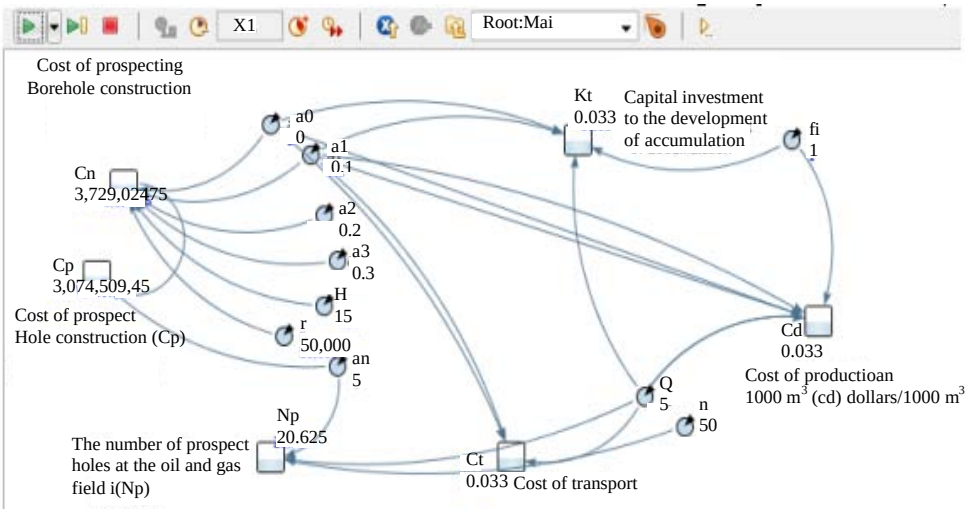

Fig. 1: The model of oil prospecting in the AnyLogic program

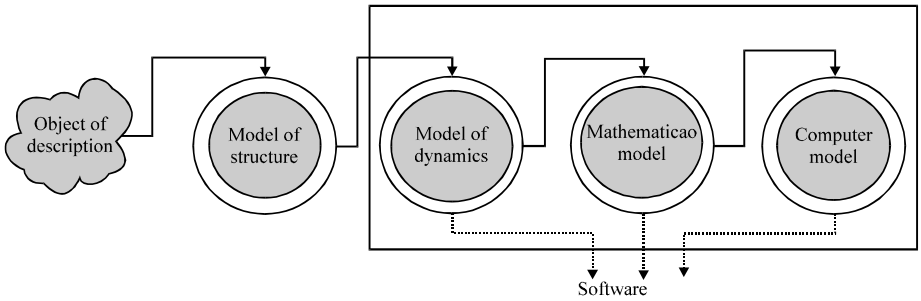

Fig. 2: General scheme of development of the model enterprises

Further, in the structural model for each sub system of oil company, objective results are defined, thereby we get more complicated but absolute system, able on detailed and complex levels to react properly on modification of conditions of object management operation. Hereafter in the Anylogicprogram it is realizing the dynamic model for each subsystem of oil company. The study supposes the portfolio set-up, so, we use mathematic model for calculation of portfolio investing of oil company. And in computer model we use the Anylogic instrument of objectively-oriented modeling with the interface of visual programming.

MATERIALS AND METHODS

Systematically dynamic model of oil company

Structural model: Key activities of typical oil company are:

- Search and exploration of hydrocarbon reservoir
- Extraction of oil, gas, gas condensate
- Repair works
- Gas, oil and products transportation on the territory of Kazakhstan and abroad

In accordance with the Fig. 3, the basis of oil company portfolio is composed by investments to corresponding type of activity. In proposed model under the character of main variables are given the following:

- Expenditures for reasonably assured resources, characterizing the sub system of oil search and exploration
- Transport logistics, reflecting the process of oil transportation
- Exploitation and modernization of petroleum field equipment as characteristics of running and capital repairs
- Oil exploration as a basis of profit making of oil company

Let us consider the formation of each variable in more details.

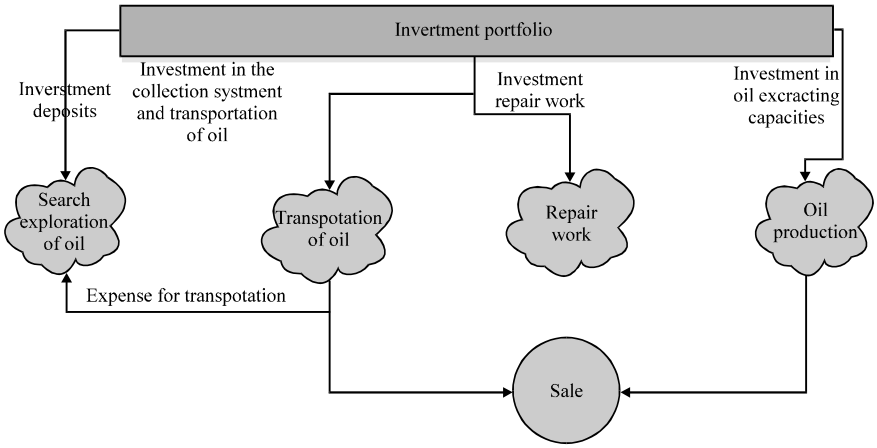

Fig. 3: Structural model of oil company and its investment portfolio

RESULTS AND DISCUSSION

Sub system of oil search and prospecting: Pride of place of sub system oil search and prospecting model goes to the equation which reflects expenditures for reasonably assured resources. Thereat, we will believe that the evaluation of deposit is characterized by relative capital investment.

Relative capital investment for each year of reservoir exploitation is a relation of accumulated investment to annual production of oil. According to Zheltov (1998) expenditure of labor and physical resources in monetary form for creation of basic enterprise funds, i.e., expenditures for sinking of boreholes, project construction of industrial oil transport, separation of hydrocarbons, desalinization and emulsion of extracted products, technological water treating and its utilization, etc. Expressed mathematically the equation will have following form:

$$\frac{dR}{dt} = \frac{K_v}{V} - S_m \quad (1)$$

Where:

R = Expenditures for explored reserves
K_v = Capital investments (thousands tenge)
V = Prospecting volume (th. bar./per day)
S_m = Expenditures for conservation of marginal fields(thousands tenge)

Let's present K_v as:

$$Kv = \sum_{i=1}^{n} a_i S_i n_i \quad (2)$$

Where:

a_i = Coefficient of proportional cost of main founds and cost of boreholes of i field $(i = \overline{1;n})$
S_i = Cost of one borehole of i field (thousands tenge)
n = Number of boreholes of i field

Here with extents of production depend on type of production:

$$V = K_r \sum_{i=1}^{n} V_i, \quad (3)$$

Where:

K_r = (From 0 till 1) coefficient which characterizes the complexity of hydrocarbon production (type of production as closer to 1 as more complex)
V_i = Volume of production of i field (th. bar./per day)

Thus, the standard form will be following:

$$\frac{dR}{dt} = \frac{\sum_{i=1}^{n} a_i s_i n_i}{K_r \sum_{i=1}^{n} V_i} - Sm \quad (4)$$

Sub system of oil transportation: Dynamics of expenditures for oil transportation will depend on volumes of costumer's consumption, for example by oil refineries. In the model we suppose that expenditures for transportation from accumulation will be reflected in expenditures for storage and that is why it demands a more detailed consideration. Surely, it is necessary to maintain accounts and control delivery values of company's transport system which also demands careful analysis. In general the model of transportation logistic will have following form:

$$\frac{dT}{dt} = C_0 \frac{D}{q} + C_1 \left(1 - \frac{D}{q}\right) \quad (5)$$

Where:

C_0 = Cost of orders (thousand tenge)
C_{1j} = Expenditures for storage (thousand tenge)
D = Use of orders (th. bar./per day)
q = Volumes of orders (th. bar./per day)

Considering that, there may be several orders, we would get:

$$\frac{dT}{dt} = \sum_{j=1}^{k} (C_{0j} \frac{D_j}{q_j} + C_{1j} (1 - \frac{D_j}{q_j}) \quad (6)$$

where, k-quantity of stocks.

Sub system of repair works: There are some technological and organizational peculiarities during oil and gas exploration which also effect on formation of operating expenses, organization of management accounting and a level of prime cost of extracted products. In the process of oil extraction the following works are performed such as assembly and disassembly of mechanical and energetic equipment, underground and aboveground repair of boreholes, maintenance of reservoir pressure, exploration and transportation of oil and gas, etc. Expenditures, related to exploitation of bottom-hole engines are included to the cost of day (of hour) work of boring apparatus as time dependent. But only shock-absorbing of bottom-hole engines sets depend on all these expenditures from time of drilling works realization.

Equipment exploitation is accompanied with continuous and inconvertible recesses in details and interferences, caused by wearing, deformations, corrosion and other factors, accumulation and overlapping of which against each other lead to reduction of working limits and refusal. Technical maintenance and equipment repair works permit to depress the risk of defects and to maintain working capacity of tools at an adequate level. Capital repair includes all types of works, classified as technical maintenance and routine repair; substitution and reconstruction of all worn parts and skids, including basic ones, state interrogation of fundament, the extent and disposition of its bottom deposits.

Moreover, it is made complete disassembly of product, its cleaning, flaw survey and change of skids, details with following assembly, regulation, testing of repaired equipment, coloring and marking.

Exploitation and modernization of oil industrial equipment suppose variable and constant costs. Variable (current) costs reflect urgent repair equipment and constant (capital) ones are costs for ongoing updating of oil company technical equipment.

Let's define mathematical equation which reflects expenditures costs for repair works: current repair of boreholes and oil equipment:

$$\frac{dP}{dt} = P_r + P_k + P_0 \quad (7)$$

where, current repair of wells and oil field equipment:

$$P_r = g_{oi} (t_{qi} V_{mi} + V_{zi})$$

Where:

g_{0i} = Coefficient, reflecting the category of complexity in i field
t_{gi} = Time of repair works in i field (hour)
t_{gi} = Cost of repair works in i field per unit time (th.tenge. per hour)
V_{zi} = Costs of spare parts (thousand tenge)

$Pk = g_{1i} V_d$ expenditures for capital repair of oilfield equipment

where, g_{1i} is percent form full volume of profit for capital repair of equipment:

$P_0 = g_{zi} V_d$ costs for technical maintenance

Where:

G_{zi} = Percent from full volume of profit for assistance of technical equipment
V_d = Profit volume per year(thousand tenge)

Subsystem of oil extraction: The period for which oil reserves can be derived reaches for 15-30 years and in some cases it can reach for 50 and even more years (for huge locations).

Volumes of oil extraction are always accompanied with the profit as from the number of extracted oil and its cost of oil distribution at the market, the company gains profits, thereby determining marketable value of the company itself.

With the aim of determining of produced oil volumes we invoke Cobb-Douglas production function. The production function has properties which determine the relation between overall production and the quantity of used factors:

$$Y_t = AK_t^{\alpha} L_t^{\beta} \quad (8)$$

Where:

Y_t = Overall output of oil per year t
K_t = Annual average fixed assets value in oil extraction per year t
L_t = Annual average number of employees in oil extraction per year t
α and β = Elasticity coefficient

which characterizes the dependence of volume and production dynamics Y_t from the volume and dynamics of production factors K_t and L_t, Aproportionality coefficient, with the help of which oil production and production factors are leading to one dimension.

Thus, let's imagine a full system of equations and model relations:

$$\frac{dR}{dt} = \frac{\sum_{i=1}^{n} a_i s_i n_i}{K_r \sum_{i=1}^{n} V_i} - S_m$$

$$\frac{dT}{dt} = C_0 \frac{D}{q} + C_1 \left(1 - \frac{D}{q}\right)$$

$$\frac{dP}{dt} = g_{0i} (t_{qi} V_{mi} + V_{zi}) + g_{1i} V_d + g_{zi} V_d$$

$$Y_t = AK_t^{\alpha} L_t^{\beta}$$

In future it is planned to refine parameters values and equations themselves as well as to study this model in more details.

CONCLUSION

Investment activity management of oil company under modern conditions is attributed to acceptance of complicated and expensive managerial conditions. Oil development is mono-productive process of production, highly specialized, from another side it is constrained to concentrate in itself a wide range of multi-sectorial scientific capabilities.

The main advantage of methodical approach, based on the simulating model building, is that the model appears to be a system of complex componential construction, where functions of factual and expert information accounting, analysis, planning and control represent unite, inseparable, interdependent process. The next advantage of the system is that it is working with information about resources of any type and destination, automatically modeling dynamics of their transformation according to input of information. The enterprise development is properly depicted by dynamic model, on which different individual characteristic should be in particular hierarchy. The study presents common questions of cooperation of structural model sub system of oil company. The following step of study will be criteria development for each sub system and determination of investment portfolio components cooperation of oil company.

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