Investments decision making on the basis of system dynamics

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Abstract. The rapid increase in the volume of incoming and processed information in oil companies has led to a change not only in the automation of the process of data processing and research, but also in the intellectualization of informational and organizational processes, building and implementing effective methods and intellectual supporting technologies of decision-making. Oil companies have always paid great attention to making the scientific and reasonable decisions about the investment scale and structure in the extraction sector to enable them to minimize business risks and make high profit. According to the theories and methods of system dynamics, a dynamic model for analyzing forecasting the scale and structure of investments for the oil industry has been built and presented in this article. As well as the problem of data extraction in intellectual information systems is described. The formulated model can be applied to analyze and predict the structure and size of the investment process as a new method and provide a basis for decision-making.

Keywords. System dynamics, Oil company, Investment, Causal loop diagrams

1 Introduction

The main purpose of information systems is the timely presentation of the necessary information to decision-makers for making effective decisions when managing with investment capital. However, during the process of the development of information technologies, intellectual informational systems have taken on a significant part of routine operations, as well as the functions of preliminary analysis and assessments. A decision-making based on the analysis of data, their behavior over time only improves and increases the effect, especially in investing.

The basis of the information system is consisted of blocks "database - DB", "rule base", "machine of logical inference - MLI". The database stores the original data. The knowledge and experience of the expert are fixed in the rule base. MLI outputs the result, interacting with the database and rule base. All three blocks should be described mathematically [1]. Therefore, the methodology of system dynamics, allowing to model complex systems at a high level of abstraction, without taking into account small details: the individual properties of individual products, events or people is the basis of an intellectual information system.

System dynamics (SD) was first developed in the late 1950s at the Massachusetts Institute of Technology under the leadership of Jay Wright Forrester in 1958 [2]. In his work, the author computatively analyzed the supply chain of the whole system. This system consists of three inventories (factory, distributors and retailers), as well as several ordering and delivery processes [3]. The system dynamics method is often chosen for complex systems, since this method is specially developed for modeling and studying complex systems with multi-parametric, nonlinear and dynamic characteristics [4]. This refers to the dynamic problems arising in complex social, managerial, economic or ecological systems, literally any dynamic systems characterized by interdependence, mutual interaction, information feedback and circular causality. The work of Jay Wright Forrester "Industrial Dynamics" [5] is still a significant exposition of philosophy and methodology in this field. At the present time, the system dynamics is applied in the economy, public policy, environmental research, protection, the construction of theory in the social sciences and other areas of management.

In more recent modeling environments, more complex integration schemes are available (although the equation written by the user may look like a simple Euler integration scheme), and temporary scenarios may not be in evidence. Important modeling environments include Vensim, Stella, iThink, PowerSim and AnyLogic.

Diagrams of feedback loops with information and circular causality are tools for conceptualization of a complex system structure and transmission of data based on the model. In the methodology of the dynamic system, a problem or a system (e.g., ecosystem, political system or mechanical system) is first represented as a causal loop diagram [6]. The causal loop diagram is a simple map of the system with all its constituent components and their interactions. Capturing interactions and consequently the feedback loops, causal loop diagram reveals the structure of the system. Understanding the structure of the system, it becomes possible to determine the behavior of the system over a certain period of time [7].

2 Prehistory and related work

2.1 Modeling in the oil industry

In this part, we will give an overview of a wide range of different models based on fossil resources based on system dynamics. Ford [8] best demonstrates the importance of models of fossil energy resources for the United States. He uses system dynamics to model and influence the strategic fuel reserve in California. As part of this study, he describes the simulation analysis that he developed for the California Energy Commission. The analysis of the simulation estimates the impact of the strategic fuel reserve (SFR), designed to limit the growth of gasoline prices during the days following the disruption of oil refining. In addition, the modeling method is characterized by a clear display of the dynamics of prices and storage, its representation of long delays that limit responsiveness to both demand and requirement, and the inclusion of unintended and presumed impacts within the same model.

In a certain analogy, Fan et al. [9] developed a model of system dynamics to capture the dynamics of investment in coal in China. The model of system dynamics simulates the behavior of the entire system caused by investments in mines, and the influence of investments in fields on the coal system is studied.

Moreover, the potential for coal production is projected in various scenarios in 2020, on the basis of which policy recommendations are proposed. Summing up, the model examines the impact of investments in state fields and geological exploration, and suggests an optimal investment size.

Tang et al. [10] predicts the oil reserves and oil production at the Daqing Oil Field in China until 2060. In particular, this document examines the state of oil fields in Daqing, the largest field in China, and forecasts its ultimate recoverable reserves by use of the SD model. Chinese politicians should pay attention to whether oil production in new oil fields effectively compensate for the reduction in the production of large brownfields. Close speaking, Li et al. [11] predict a rise in natural gas consumption in China until 2030. They estimate gas consumption in China by the method of sectoral division, which shows a different trend of growth in gas consumption in various industries. From a general point, a forecast results give some reasonable preconditions for the development of the gas industry in China.

Hosseini et al. [12] to use the SD methodology for modeling of a peak of oil production in Iran and the assessment of impacts. In this study they consider the main factors influencing the peak of oil production in Iran, using the SD approach. The developed model can help practitioners, especially politicians, in the oil sector to obtain a systematic and comprehensive understanding of the influencing factors and relationships that led to the peak of oil in Iran.

2.2 Tools for modelling and simulation

For the analysis of economic processes, simulation models developments are created and are being created currently on the basis of special environments. At this point in time, the most common environment of simulation models developments such as Stella (Ithink), Anylogic Vensim, Powersim are well-known. They allow not only quickly create simulation models using simple visual tools, but also to analyze the work of created models and to use these models to assess the impact of management decisions on the course of economic processes in modeled systems.

The Stella approach to systems modeling has some common features with its predecessor, the simulation language Dynamo. Dynamo clearly defined "stocks" (tanks), and flows (inputs and outputs) as key variables in the system vocabulary, which owns Stella [13]. Stella users are provided a graphical user interface where they can create graphical models of the system using four basic principles: stocks, flows, converters and connectors [14]. Communication between the transmitters (which transmit the transforming variables) and other elements can be done using converters. Users can enter values for stocks, flows and converters (including using the many built-in functions) [15]. Stella does not distinguish between the external and intermediate variables within the system; All of them are converters [16].

AnyLogic is a multi-model simulation modeling tool developed by the AnyLogic company. It supports agent-based modelling methodology, discrete events and system dynamics.

Simulation modelling Language Powersim can be used for modelling both simple and complex systems. It is known that complex systems are characterized by a multiplicity of descriptions. So for them it is impossible to build the only true model, but you can only describe their behavior with the help of those or other models, reflecting the characteristic behavior of the simulated systems in specific situations.

3 System dynamics model of oil company

3.1 Model development methodology

Let's consider a design pattern of a system dynamic model, which will have a form as shown in Figure 1. The model elements and the relationships between them define the structure of the model. System dynamics is based on the theory of feedback and integrates such subjects as information theory, management science and decision theory [17]. With principles defining the system function of the system, the whole system can be a model as a graph structure and functional relations, it then constructs a feedback loop with the theory of feedback control, finally, establishes the dynamic model of the system and models it using a computer [18]. Oil company is engaged in exploration, development and production of oil and gas. As a result, investments in exploration and production are to be divided into four areas, including investment in exploration, investment in development and investment in operational services. Investments in the exploration operations consist of investment in geophysical and geochemical exploration, investment in exploration wells and other relative investments. Development investments consist of investments in wells, investment in the construction of onshore facilities and other related investments. Investment in operational services encompass investments in power generation and communication, as well as investments in security and protection of the environment [19].

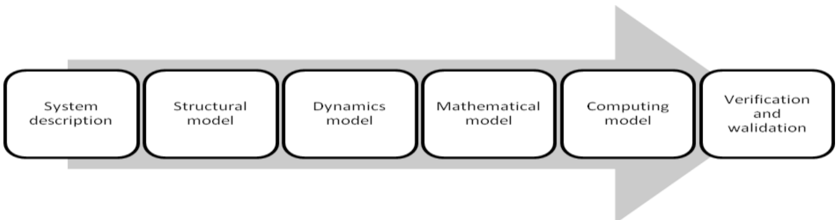

Fig. 1. Methodology of dynamics model development

3.2 Description of oil company and its structural model

In the proposed model (Figure 2), the nature of the main variables is expressed by the following:

- expenses for the provided resources, characterizing the subsystem of oil prospecting and exploration;
- transport logistics, reflecting the process of oil transportation;

- operation and modernization of oil field equipment as characteristics of current and major repairs;
- oil exploration, as the basis for profit of the oil company.

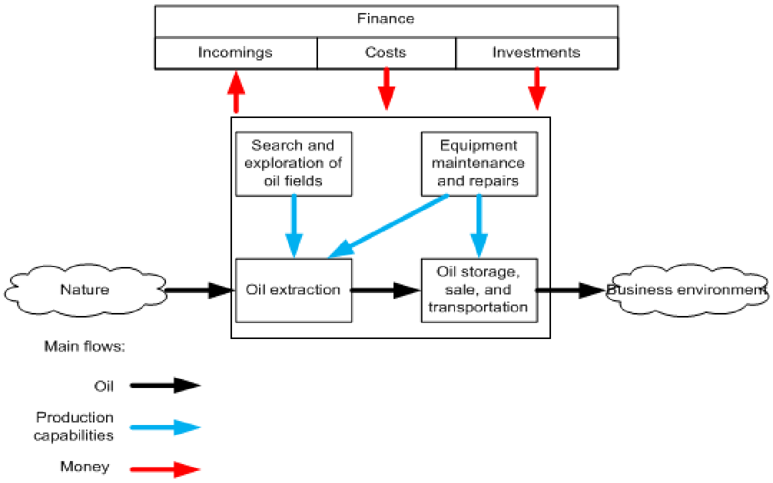

Fig. 2. Structural model of oil company

3.3 Development of causal loop sub-models

Sub-system: oil extraction, search and exploration of oil fields

The model of the subsystem of a field prospecting and exploration is based on an equation that reflects the costs of explored reserves of resources. In this case, we will assume that the assessment of the field is characterized by a relative capital investment.

A relative capital investment for each year of field development is the ratio of accumulated investments to the annual oil production. According to Zheltov Y. P. [19] it is "the expenditure of labor and material resources in monetary terms for the creation of fixed assets of the enterprise, i.e. expenses for drilling of the wells, construction of commercial oil transport facilities, separation of hydrocarbons, demineralization and demulsions of extracted products, treatment of process water and its utilization, etc. ".

In mathematical expression, the equation will have the following form:

$$\frac{dR}{dt} = \frac{K_v}{V} - S_m \tag{1}$$

where R – the costs of proven reserves of resources, K_v – capital investment (thousand tenge), V – volume of exploration, (thousand barrels per day), S_m – costs of the conservation of marginal fields (thousand tenge per thousand bar).

Imagine K_v as:

$$K_v = \sum_{i=1}^{n} a_i S_i n_i \tag{2}$$

where a_i – coefficient of a proportional value of fixed assets and cost of wells of the i-th field ($i = \overline{1, n}$), S_i – cost of one well of the i-th field (thousand tenge), n – number of wells of the i-th field.

At the same time, production volumes depend on the type of production:

$$V = K_r \sum_{i=1}^{n} V_i \tag{3}$$

where K_r (from 0 to 1) – coefficient, characterizing the complexity of hydrocarbon production (type of production, the closer to 1 the more complex), V_i – volume of production of the i-th field (thousand barrels per day).

Thus, the general view is as follows:

$$\frac{dR}{dt} = \frac{\sum_{i=1}^{n} a_i S_i n_i}{K_r \sum_{i=1}^{n} V_i} - S_m \tag{4}$$

Sub-system: Oil storage, sale, and transportation

Dynamics of expenses for oil transportation will depend on the volume of consumption of customers, such as refineries. In the model we assume that the transportation costs from the field will be reflected in the cost of storage and it requires more detailed consideration. Of course, accounting and capacity of the transport system is necessary, which also requires a more careful analysis.

The general view of a transport logistics model as follows:

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

where C_0, cost of orders (thousand tenge), C_{1j} – cost for storage in a warehouse (thousand tenge), D – consumption of orders (thousand barrels per day), q – volumes of orders, (thousand barrels per day), T - transportation cost.

Given that there can be several orders we, for k – number of stocks, get:

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

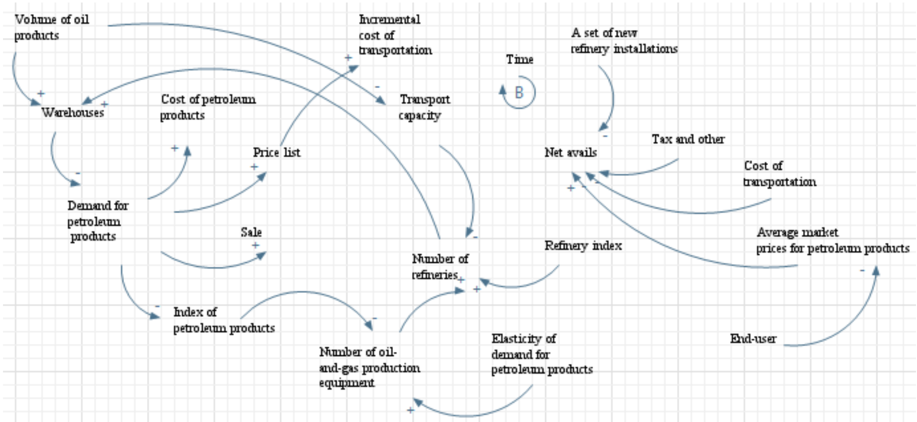

Fig. 3. Model oil storage, sale, and transportation

Sub-system: Equipment maintenance and repairs

During oil and gas extraction there are technological and organizational features that affect the formation of production costs, the organization of management accounting and the level of the cost of production.

In the process of oil production, such works as installation and dismantling of mechanical and power equipment, underground and aboveground well repair, maintenance of reservoir pressure, collection and transportation of oil and gas, etc., are being done. The costs associated with the operation of downhole motors are included in the cost of a day (hour) of operation of the rig as time-dependent. But, only the depreciation of the downhole motor kit depends on all these costs from the time of drilling.

The operation of the equipment is accompanied by continuous and irreversible changes in the parts and connections caused by wear, deformation, corrosion and other factors, the accumulation and overlap of which lead to a decrease in working characteristics and failure. Works on maintenance and repair of equipment allow you to reduce the possibility of malfunctions and maintain the performance of products at the proper level.

The size of the overhaul includes all work types related to maintenance and routine maintenance; replacement and restoration of all worn out parts and assemblies, including basic ones; the determination of the state of the foundation, the magnitude and nature of its draught. With all this a complete disassembly of the product, washing, defectoscopy and substitution of units, parts, with the following assembly, adjustment, testing of repaired equipment, painting and marking is being done.

The maintenance and improvement of oilfield equipment involves variable and fixed costs. Variables (current) reflect the urgent repairs of equipment, and permanent (capital) is the cost of constant updating of technical equipment of the oil company.

A mathematical equation reflecting the monetary cost of repairs is:

$$\frac{dP}{dt} = P_r + P_k + P_0 \tag{7}$$

where: $P_r = g_{0i}(t_{qi}V_{mi} + V_{zi})$ – current repair of wells and oilfield equipment; g_{0i} – coefficient, reflecting the category of repair complexity on the i-th field, t_{qi} – time of repair work on the i-th field (час.), V_{mi} – cost of repair works on i-th deposits per unit of time (thousand tenge per hour), V_{zi} – t e cost of spare parts (thousand tenge); $P_k = g_{1i}V_d$ – costs on overhaul of oilfield equipment; g_{1i} – share of the total profit for the overhaul of equipment; $P_o = g_{2i}V_d$ – cost of maintenance; g_{2i} – share of total profit for technical support of equipment, V_d – amount of profit per year (thousand tenge).

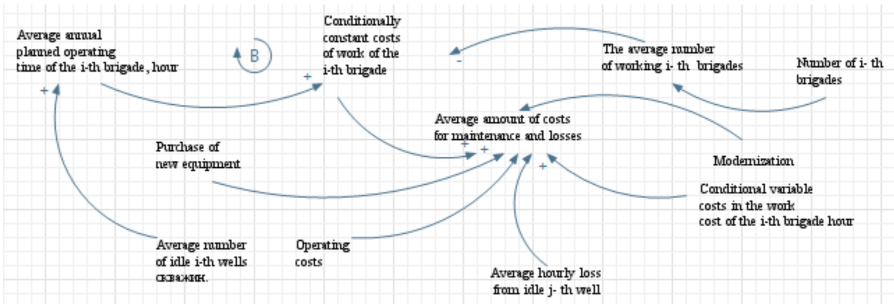

Fig. 4. Model of implementations of maintenance and repairs

Sub-system: Finance

Oil companies pay great attention to the analysis and forecast of investment in exploration and production, in terms of scale and structure, and can then take appropriate action to adjust according to changing situations. Many methods are available as methods of analysis and forecasting such as time series analysis, regression analysis and econometric methods [12].

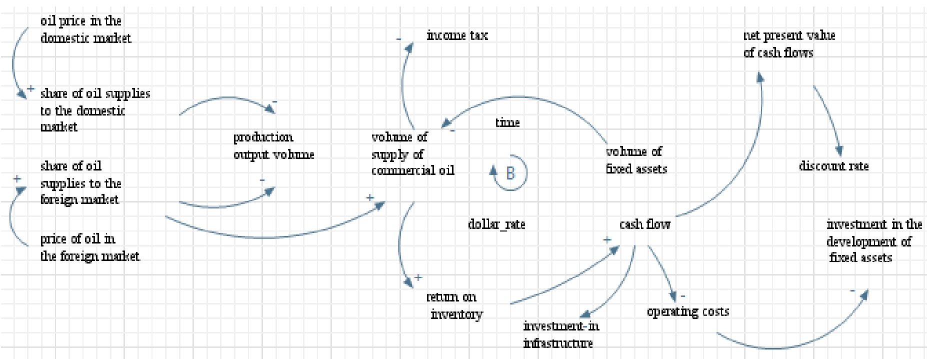

Fig. 5. Model of implementations of cash flows

4 The problem of data extraction in intellectual information systems

Intellectual information system is based on the concept of using the knowledge base to generate algorithms for solving investment problems in an oil company will allow: to diagnose the company's condition; help in crisis management; choose the optimal solutions according to the company's development strategy and its investment activities; economic analysis of the company's activity; strategically plan; to analyze the investment, evaluate the risk; to form a portfolio of securities, etc.

Every intelligent information system, taking into account adaptability to the changes in the subject area and information needs of users, performs the following functions: perceives user-entered information requests and necessary initial data, processes entered and stored data in the system in accordance with the known algorithm, and generates the required output information.

When creating systems of managing with knowledge base, already known and specially developed data models are used. For example, in a number of works, knowledge bases, realized by means of relational DBMS are described. Therefore, today the development of systems requires the realization of easier and more convenient access to databases. It is important to make access and manipulation easier in complex databases.

And it means that intelligent databases differ from conventional databases by the possibility of retrieving the required information upon request, which can not be exactly stored, but can be extracted from the database.

The technology of extracting the right data from large databases is the main problem. Optimization is important for users, since with this ability they need to know only a few rules and commands for using the database.

It is required to perform a search on the condition, which must be further defined in the course of solving the problem. Intellectual system without the help of the user on the structure of the database in itself builds the path to access the data files. The query is formulated in a dialogue with the user, the sequence of steps of which should be performed in the most convenient form for the user. This task is set in designing an information system of supporting decision-making of investment in an oil company.

5 Conclusions and future work

Management of investment activity of oil companies in modern conditions is connected with the adoption of complex and expensive management conditions. Oil development is the mono-productive production process and is highly specialized; on the other hand, it had to concentrate a wide range of multidisciplinary scientific capabilities.

The main advantage of the methodological approach based on modeling of model building is that the model is a complex component of the building, where the functions of actual and expert information on accounting, analysis, planning and management represent the union, indivisible, interdependent process. Another advantage of the system is that it operates with resources of any type and destination, automatically simulating the dynamics of their transformation in accordance with the input information. A dynamic model in which different individual characteristics should be in a particular hierarchy properly describes the development of the company. The article presents the general issues of interaction of the structural model subsystems of the oil company. The next step will be to develop criteria for each subsystem and identify components of the investment portfolio for the oil company.

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